Twenty-eighth Annual Report

of the

New York State College of Agriculture

at Cornell University

and of the

Agricultural Experiment Station

Established under the Direction
of Cornell University
Ithaca, New York

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TWENTY-EIGHTH ANNUAL REPORT

OF THE

New York State College of Agriculture at Cornell University and of the Agricultural Experiment Station Established under the Direction of Cornell University

STATE OF NEW YORK

DEPARTMENT OF AGRICULTURE

ALBANY, January 15, 1916

To the Honorable the Legislature of the State of New York:

In accordance with the provisions of the statutes relating thereto, I have the honor to transmit herewith the Twenty-eighth Annual Report of the New York State College of Agriculture at Cornell University, as a part of the Twenty-third Annual Report of the Commissioner of Agriculture.

CHARLES S. WILSON,

Commissioner of Agriculture.

NEW YORK STATE COLLEGE OF AGRICULTURE

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Henry Emil Allanson, Private Secretary to the Dean.

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Charles Edward Hunn, Assistant in Plant Propagation.
Lucy Harriet Ashton, Assistant to the Registrar.
Anna Mary Atwater, Laboratory Assistant in Plant Breeding.
Laura McLallen Van Auken, Clerk in Department of Dairy Industry.
Alfred Evan Boicourt, Foreman of Experimental Plant, Poultry Husbandry.
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Herbert Percival Buchan, Foreman of Incubation Division, Poultry Husbandry.
William A. Frederick, Landscape Gardener.
Herbert W. Teeter, Superintendent of Plant Breeding Gardens.
Mrs. E. H. Starr, Clerk in Department of Poultry Husbandry.

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AGRICULTURAL EXPERIMENT STATION

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LELA G. GROSS, Assistant Editor.

December 27, 1915

The Governor of the State of New York,
Albany, New York.

The Secretary of the Treasury,
Washington, D. C.

The Secretary of Agriculture,
Washington, D. C.

The Commissioner of Agriculture,
Albany, New York.

In conformity with the law and practices of former years, I beg to submit on behalf of Cornell University the accompanying report of the New York State College of Agriculture for the year 1914–15, signed by the Dean of the College.

This report, together with the abstracts of the work of the different departments, and copies of the various publications of the year, set forth in such detail the activities of the College that it is unnecessary to dwell at length upon any particular feature of the work.

Respectfully submitted,
JACOB GOULD SCHURMAN,
President of Cornell University.

REPORT OF THE DEAN OF THE NEW YORK STATE COLLEGE OF AGRICULTURE

November 23, 1915

To the President of the University:

Sir: I have the honor to submit the accompanying report of the New York State College of Agriculture for the year 1914–15.

On the whole, the year has been a prosperous one for the College of Agriculture.

EDUCATIONAL POLICIES AND IDEALS

Necessarily, however, there is no permanency as yet in the policies and the ideals that should govern in the teaching work of a college of agriculture. Fundamentally, the institution should stand for all those things that go to the making of men and women, rather than the mere training of men and women. Fundamentally, again, it is imperative that in the shaping of policies and the development of ideals we should constantly aim to teach those things that are related to life itself. Agriculture, and all that it involves and implies, furnishes as broad and as basic a background for a liberal education as any subject now used, or hitherto used, in the training of the human mind.

COURSES OF INSTRUCTION

The College of Agriculture offers a regular four-years course in agriculture leading to the degree of bachelor of science, a four-years professional course in home economics, a four-years professional course in forestry with an additional year in the Graduate School leading to the degree of master in forestry, a four-years professional course in rural education, and a four-years professional course in landscape art with an additional year in the Graduate School leading to the degree of master in landscape design.

In addition, the College offers 55 short courses, of twelve weeks each, for the benefit of those who desire to come directly from the farm and the farm home. There are two summer schools, one for teachers and one for those interested in country life leadership.

Farmers' Week has come to be recognized as a valuable feature in bringing the farmers and the farmers' wives of the State in close contact with the College, the attendance at the last one, held February 8 to 13, 1915, reaching over four thousand.

THE THIRD TERM

A third, or summer, term in the College of Agriculture is fully established to utilize the long summer vacation for the teaching of certain timely subjects.

RURAL EDUCATION

In the training of teachers for carrying on agricultural instruction, the College of Agriculture must assume and maintain leadership, for its real function will be to train teachers who will themselves become teachers of teachers. The College has, or should have, the background of environment and facts that will enable it to turn out teachers of the first rank, who will be the recognized leaders in the new movement for such forms of rural education as will adapt the work of the elementary, the secondary, and the normal school to the lives of those whom they are required to instruct.

The courses of instruction are so shaped as to prepare for general scholarship, to train in the philosophy and principles of education, and to assure a grasp of agricultural technique and out-of-door problems that will lead to permanency in agricultural educational effort. In any such work the relations with all the other departments of the College, with the University as a whole, and with those agencies in the State charged with the conduct of educational work in general, must be closely cooperative and cordial.

THE COLLEGE OF AGRICULTURE AND FORESTRY

In New York State, with a large proportion of land which not only is now forested but should ultimately remain so, the forest problem is an important one. It is particularly important in connection with care of the woodlot on the farm, for these woodlots contain one-third of the timber area.

Education in forestry must be definite, thoroughly organized, and sound. Because foresters are pioneers in what is comparatively a new profession, they need to have a broad and basic training. As an indication of this it must be remembered that the whole conservation movement, which is said to have affected the American people more profoundly than any other issue within the past half century, was fostered and brought about by those who first began to think about the future of the country's natural resources through a study of its forests.

The work in the Department of Forestry at the College of Agriculture keeps all these points in view. It is carefully correlated with other work in science and agriculture, and for this reason it has the peculiar advantages that come about through the possibility of associating a specialized study with others having a direct bearing on it.

The instruction in forestry is designed to meet the needs of several classes of students: (1) students of general agriculture who wish elementary

instruction in the case of woodlands and in forest planting and forest nursery work; (2) prospective teachers, business men, lawyers, and others who desire an understanding of the place of forestry in the life of a nation; (3) technical students in other lines who wish one or more technical forestry courses, such as wood technology; (4) professional forestry students.

An important part of the work of the Department is its effort to be of direct help to owners of forest lands in New York State.

The College has all the necessary facilities for carrying on forestry work of a high order, save one, and that is a large wooded tract on which experiments in the field of forest research may be carried out. Even yet much of the work in American forestry is being based on original studies made abroad. German forest methods, in particular, have influenced those of America; yet American foresters have been forced to the conclusion that American conditions require an American system. Our problems cannot be solved without adequate means for research work on the ground. General research work in forestry, as in other natural sciences, is bound to fall on the universities. In addition, a forest school should have, even for practical demonstrations, a sufficient tract to give results on a large scale. For both these reasons, therefore, the greatest need of the Department of Forestry of the State College of Agriculture is a forest tract on which field studies and experiments may be conducted.

EXTENSION WORK

The extension work of the College has received a new impetus during the year, as a result of the passage of a federal law known as the Smith-Lever Cooperative Extension Act. This Act provides for cooperative agricultural extension work between the agricultural colleges in the several States and the United States Department of Agriculture. The law specifically provides that the cooperative agricultural extension work "shall consist in the giving of instruction and practical demonstrations in agriculture and home economics to persons not attending or resident in said colleges, and imparting to such persons information on such subjects, through field demonstrations, publications, and otherwise." It provides further "that the work to be conducted in the State shall be mutually agreed upon by the Secretary of Agriculture and the state agricultural college receiving the benefits of the Act." It is the intent of this Act to make it practicable to carry to the people, on their farms and in their own homes, accumulated agricultural information that will prove useful and helpful. The fundamental idea of the work is demonstrational; that is, to teach by showing how to do things rather than by talking about how to do them. By virtue of this Act, the State College of Agriculture receives for the fiscal year 1914–15 the sum of $10,000,

and a like amount each year thereafter. In addition to the $10,000, the State College of Agriculture will receive an increase for the next fiscal year of $23,443, and each following year an increase of $19,536, until the total aggregates $170,195, providing the State meets this cumulative sum each year with an equal amount.

The wording of the Act is such that the funds necessary to meet the federal funds may be appropriated by the Legislature or by counties or municipalities, or they may be contributed by private individuals or by groups of individuals. In all cases, however, the funds contributed within the State must be turned over to the State College of Agriculture, since that is the responsible agent handling the funds under the terms of the Act. The Legislature of the State of New York was not in session when the Act was finally passed in 1914. Under the terms of the Act, however, the Governor of the State accepted the same, and designated the State College of Agriculture at Cornell University as the recipient of the funds, and a memorandum of understanding was entered into between the New York State College of Agriculture and the United States Department of Agriculture, regarding the extension work in agriculture and home economics in the State.

The extension service of the College may be defined as all those enterprises to help the people on the farms and in their own homes to solve the problems of better living and better farming. It has no features of exploitation. The very aim of the work presupposes knowledge to be disseminated. The best types of extension work are those that result in some permanent educational advancement.

In formulating the plans for extension work under the terms of the Lever Act, it is proposed to coordinate all these activities. The work will be conducted in accordance with a definite plan of project and subproject statements, as required by the Federal Government. These projects and subprojects will show the details of the work and the relationships established between the various departments.

There were held, in the season 1914–15, forty-seven farm demonstration schools in twenty-six counties. The total enrollment was 1741, the average enrollment 37, and the average attendance per session 25. In Farmers' Week there were 350 lectures and demonstrations. Altogether, there were approximately 1186 meetings in which the work of the College was presented to the public. Many farms and farm homes are reached through correspondence, there being over twenty thousand letters sent out each year from the Department of Extension Teaching alone. In addition to the farm demonstration schools enumerated above, there were thirty-eight demonstration schools in home economics. Some 56,000 persons were reached through the reading courses. Another method

that reached more than six thousand persons was through demonstration cars. Four such cars were sent out during the year.

The Department of Home Economics has recognized the need of helping farm women and girls by making living conditions easier and pleasanter. More and more the Farmers' Week conferences are being attended, not only by the farmers themselves, but also by their wives and daughters.

WORK OF THE FARM BUREAUS

On May 1, 1915, there were thirty organized farm bureaus in New York State. These farm bureaus are managed by associations of farmers in the county through an executive committee, which usually consists of seven men. The actual work of the manager in the field, his demonstrations, meetings, and other activities, are carried on by means of an advisory council composed of a representative in each community. The total number of these officers and committeemen who are cooperating with the managers in carrying forward this work is about 1100. The total membership in the associations controlling the work in the counties is approximately 9000.

The total estimated resources for the coming year are $107,271, or a little less than $4000 per county. This is an increase of approximately $16,000 over 1914, when the average resources per county amounted to $3500, of which $3185 was expended.

Some very effective demonstration work has been organized and carried out during the spring. As an example of this work, Manager Merchant's campaign for the control of oat smut in Montgomery County may be mentioned. At 14 oat smut demonstrations, attended by 396 farmers, Mr. Merchant himself treated 900 bushels of oats, sufficient to plant 400 acres. The men who attended these demonstrations and who were influenced to treat the seed for their oat acreage will plant a total of about 5000 acres this spring. In another case, in Dutchess County, Manager Lacy has secured pledges and given instructions for the treatment of seed oats to plant nearly 1500 acres. In Cattaraugus County, at 11 demonstrations held by Manager Crofoot, with Professor Barrus, of the College, assisting, pledges were secured for the treatment of the oats to plant 800 acres. In Monroe County, Manager Toan held 16 pruning demonstrations attended by 580 men. These are good examples of similar demonstration work being carried on throughout the State. It is expected that at least 2000 demonstrations will be held in the 31 farm bureau counties this year, and if the present rate of attendance at these keeps up, not less than 10,000, and perhaps 15,000, persons will have their attention called to this work.

ORGANIZATION OF AN INFORMATIONAL SERVICE

Beginning with the middle of December, 1914, the College organized a new Informational Service for the purpose of securing a wider dissemination of the facts gathered through the research work of the College and the experiment station. Since most farmers are reading the agricultural journals and the rural press generally, it was thought that the College might develop a plan of giving helpful and timely information through these papers.

This is no more than a logical third step in the development of the College's teaching. The first step was the teaching of resident students at the College; the second step came about through the development of the extension work; in the third step, it is intended that the Informational Service shall reach a much larger audience through mediums which are read by practically every one who reads at all.

Four months of work already done indicate a strong spirit of cooperation on the part of the press of the State. The papers have freely used the material sent out from the College, and, from actual news clippings received, a total circulation of more than twenty-five million separate printings for the various items has been obtained. These figures manifestly represent only a portion of the printings of information sent out by the College. The total circulation of the College's regular publications of all sorts — circulars, bulletins, reading-course lessons, and the like — is between two and three million copies a year. It can be seen, therefore, that the Informational Service reaches a vastly larger number; and its cost, as compared to that of other more formal documents, is almost negligible.

The single purpose governing the work is to give help to the persons who read the item; always the matter is presented in the briefest and clearest form. It carries with it no exploitation of the institution or of any individual. Its sole aim must be to benefit the reader, not the person who sends it out.

The work has already been productive of tangible results; it has brought about a more general and more intelligent demand for the publications issued by the College; it has measurably increased attendance at farmers' meetings and demonstration schools; and it has invoked larger and more general appeals to the College for specific information on farm problems.

FARM PRACTICE IN AGRICULTURAL EDUCATIONAL WORK

The New York State College of Agriculture has heretofore followed a plan, so far as it was practicable, of encouraging students without farm practice experience to get it through summer work on farms. It has not been possible to organize this work in a systematic way, hence a con-

siderable number of the students have failed to get the required practice; and the work and the relations to the College of those who did go on farms not under the College's supervision have not been all that could be desired. A plan has been perfected and was put in operation on April 1, 1915, whereby the work will be systematically organized and carried on under the supervision of Professor A. C. King, who has been appointed Professor of Farm Practice in the Department of Farm Practice. Professor King's first work is the making of a list, or inventory, of private farms whose owners are sympathetic toward students and will be willing to give them a trial and to pay wages that are fair for the work performed. Each farm must be personally visited by Professor King, the owner interviewed, and the plan thoroughly discussed and understood. The farms will be situated so that the students will get a variety of work and experience. They will represent the average in equipment and management. Reports from both students and employers will be regularly received, and a systematic plan of follow-up procedure will be maintained.

CHANGES IN COLLEGE STAFF

There have been but few changes in the professional staff during the year. Professor Bristow Adams, of the United States Forest Service, was appointed Professor of Extension, Information Service. Dr. Cornelius Betten, of Lake Forest University, was appointed Secretary, with the title of Professor, the appointment to take effect on April 1, 1915. He succeeds Professor A. R. Mann, who has been appointed to the position of Professor of Rural Social Organization. Professor Charles S. Wilson, head of the Department of Pomology, resigned on April 1, 1915, to become Commissioner of Agriculture of the State of New York. Cornell University and the College of Agriculture are honored for the second time by the selection of one of its staff for this high office.

Professor A. C. King, of Trumansburg, was appointed Professor of Farm Practice, the appointment becoming effective on April 1, 1915. Professor King is a graduate of Cornell University, College of Agriculture, class of 1899, and has assisted in the extension work of the College for the past three years.

BUILDINGS AND EQUIPMENT

Since the organization of the State College of Agriculture there has been expended or appropriated for buildings $1,248,200, and for equipment $228,000, making a total for buildings and equipment of $1,476,200. During the year the Agronomy Building, costing $100,000 (not including $20,000 for equipment), has been completed and is occupied. The Animal Husbandry Building, costing $91,000 (with $20,000 for equipment), has also been occupied. The Stock Judging Pavilion, costing $38,000,

has been finished and is now in use. The auxiliary poultry buildings, costing $25,000, are now nearing completion. Contracts for additions to the greenhouses, costing $30,000, have been let, and plans for tool, pig, and sheep barns are practically ready to be advertised for bids. A portion of the main tunnels and underground mains for the heating system, costing $35,000, was completed on May 5. Plans for a Plant Industry Building, for which provision was made at the last session of the Legislature, are now being made by architects under the supervision of the State Architect.

REGISTRATION OF STUDENTS IN THE COLLEGE OF AGRICULTURE FOR THE YEAR 1914-1915

The registration of students in the College of Agriculture for the year 1914–15 (including the winter courses and the 1914 summer school) is as follows:

Graduate students		168
Regular students:		
Freshmen	550	
Sophomores	388	
Juniors	331	
Seniors	275	
		1,544
Special students		124
Total full-year students		1,836
Winter courses:		
Agriculture (General)	269	
Dairy Industry	108	
Poultry Husbandry	69	
Fruit Growing	42	
Home Economics	39	
Vegetable Gardening	14	
Flower Growing	8	
		549
Summer School (1914)		388
Total		2,773

Respectfully submitted,

BEVERLY T. GALLOWAY,

Dean of the New York State College of Agriculture.

INFORMATION SERVICE

With the beginning of the calendar year an Information Service was established in the College of Agriculture, which took over the editorial work on publications of the Experiment Station and of the College, and in fact all the effort that had to do with the contact between the College and the people of the State by means of the printed word. The two general lines of work which it has carried forward have been, first, the editorial revision of established publications, and second, an Information Service through the agricultural and rural press of the State.

The Information Service has been a success from the start, because the newspapers have cooperated to a marked degree in giving space for helpful and timely information for advancing the rural interests of the State. The results of this service have been shown in a larger and more intelligent demand for the publications of the College and the Experiment Station, and in an increase in the use of the facilities which the College has for aiding the farmer and the farmer's wife.

Through a press clipping service it has been possible to get an indication of the use which has been made of the information sent out. This information has had as its sole aim the advancement of the interests of the farmer, and has consistently avoided any exploitation of the institution or of individuals. The aggregate circulation of items, as shown by press clippings up to October 1, was more than twenty-five million actual printings, based on the circulation of the papers in which the various items appeared. It is proposed to develop the Service even further for the popular dissemination of useful facts. A large part of the knowledge acquired by the Cornell investigators can be made readily available in this way without the expense and formality of a pretentious bulletin or circular; also, some of the information, in order to be of value to the farmers, has to be given out immediately. For all such material the cooperation of the press of the State has proved of inestimable value.

REPORT ON EDITORIAL WORK

October 1, 1914, to September 30, 1915

	Number of pages in printed bulletin	Number of copies printed
BULLETINS:		
283 (Second revised reprint) The control of insect pests and plant diseases (Departments of Entomology and Plant Pathology)	38	10,000
291 (Revised reprint) The apple redbugs (Department of Entomology)	16	16,000

	Number of pages in printed bulletin	Number of copies printed
BULLETINS (*continued*):		
353 The interior quality of market eggs (Department of Poultry Husbandry)	48	60,000
354 Further experiments in the dusting and spraying of apples (Departments of Plant Pathology and Entomology)	48	16,000
355 Two factors causing variation in the weight of print butter (Department of Dairy Industry)	16	10,000
356 The control of apple insects in Clinton County (Department of Entomology)	20	5,000
357 The cost of milk production (Department of Animal Husbandry)	32	50,000
358 Some important leaf diseases of nursery stock (Department of Plant Pathology)	64	7,000
359 Some external parasites of poultry, with special reference to Mallophaga; with directions for their control (Department of Entomology)	40	5,000
360 Variation in the tests for fat in cream and skimmed milk (Department of Dairy Industry)	24	6,000
361 The home grounds (Department of Landscape Art)	144	30,000
Total	490	215,000
MEMOIRS:		
5 Physiological studies of Bacillus radicicola of Canada field pea (Department of Botany)	84	5,000
6 Fusaria of potatoes (Department of Plant Pathology)	188	7,000
7 Senile changes in leaves of Vitis vulpina L. and certain other plants (Department of Botany)	100	7,000
8 A bacterial disease of stone fruits (Department of Plant Pathology)	64	7,500
Total	436	26,500
CIRCULARS:		
12 (Revised reprint) The chemical analysis of soil (Department of Soil Technology)	4	6,000
27 The curing of meat and meat products on the farm (Department of Animal Husbandry)	16	5,000
28 Apple cankers and their control (Department of Plant Pathology)	12	25,000
29 Poultry parasites: some of the external parasites that infest domestic fowls, with suggestions for their control (Department of Entomology)	12	60,000
30 Methods of making some of the soft cheeses (Department of Dairy Industry)	24	6,000
31 Fall spraying for peach leaf curl (Department of Plant Pathology)	12	15,000
Total	80	117,000
READING COURSE LESSONS FOR THE FARM:		
74 Introduction to the principles of soil fertility (Department of Soil Technology)	16	50,000
Supplement	2	(45,000)
76 Birds in their relation to agriculture in New York State (Department of Entomology)	40	50,000
Supplement	4	(45,000)

	Number of pages in printed bulletin	Number of copies printed
READING COURSE LESSONS FOR THE FARM (*continued*):		
78 Land drainage and soil efficiency (Department of Soil Technology)	16	60,000
Supplement	4	(55,000)
80 Incubation (Department of Poultry Husbandry)	28	60,000
Supplement	4	(55,000)
82 Cream separation (Department of Dairy Industry)	20	35,000
Supplement	4	(30,000)
84 Insects injurious to the fruit of the apple (Department of Entomology)	24	50,000
Supplement	4	(45,000)
86 The production of clean milk (Department of Dairy Industry)	16	60,000
Supplement	4	(55,000)
88 Feeding young chickens (Department of Poultry Husbandry)	20	60,000
Supplement	4	(55,000)
90 Alfalfa for New York (Department of Farm Crops)	16	50,000
Supplement	4	(45,000)
92 Summer care of the home vegetable garden (Department of Vegetable Gardening)	16	50,000
Supplement	4	(45,000)
94 The farm fishpond (Department of Entomology)	40	50,000
Supplement	4	(45,000)
96 The surroundings of the farm home (Department of Landscape Art)	24	60,000
Supplement	4	(55,000)
Total	322	*635,000
READING COURSE LESSONS FOR THE FARM HOME:		
73 Making cake.— Part I (Department of Home Economics)	20	50,000
Supplement	2	(50,000)
75 Making cake.— Part II (Department of Home Economics)	24	50,000
Supplement	4	(50,000)
77 Songs that live (Department of Home Economics)	32	60,000
(No supplement)		
79 Programs for use in study clubs (Department of Home Economics)	24	50,000
(No supplement)		
81 Potatoes in the dietary (Department of Home Economics)	16	50,000
Supplement	4	(50,000)
83 Raising vegetables for canning (Department of Vegetable Gardening)	24	50,000
Supplement	4	(50,000)
85 The arrangement of household furnishings (Department of Home Economics)	12	55,000
Supplement	4	(55,000)
87 The decorative use of flowers (Department of Home Economics)	28	50,000
(No supplement)		
89 Beans and similar vegetables as food (Department of Home Economics)	20	50,000
Supplement	4	(50,000)

*Supplements not included, as printed with lessons.

	Number of pages in printed bulletin	Number of copies printed
READING COURSE LESSONS FOR THE FARM HOME (*continued*):		
91 The daily life of primitive woman (Department of Home Economics)	56	50,000
(No supplement)		
93 Farm home demonstration schools (Department of Home Economics)	16	50,000
Supplement	4	(50,000)
95 The fireless cooker and its uses (Department of Home Economics)	24	50,000
Supplement	4	(50,000)
Total	326	*615,000
RURAL SCHOOL LEAFLETS:		
November, 1914 (Department of Rural Education)	32	200,000
January, 1915 (Department of Rural Education)	24	200,000
March, 1915 (Department of Rural Education)	48	200,000
September, 1915 (Department of Rural Education)	340	55,000
Total	444	655,000
ANNUAL REPORT FOR 1914 (in two volumes)	2,631	2,000
ANNOUNCEMENTS:		
Regular announcement of courses	76	18,000
Announcement of winter courses	40	9,000
Total	116	27,000
FARM BUREAU CIRCULARS:		
5 Niagara county: an account of its agriculture and of its farm bureau	24	4,000
6 Summary report of farm bureau work in New York State for the calendar year 1914	84	10,000
Total	108	14,000
EXTENSION CIRCULARS:		
3 (Revised reprint) Means by which the State College of Agriculture is endeavoring to serve the farmers of New York (Department of Extension Teaching)	4	7,500
9 The department of vegetable gardening and its work (Department of Vegetable Gardening)	8	3,000
10 Cooperation in agriculture, and the factors that make for success (Beverly T. Galloway, Dean)	6	10,000
11 (No circular numbered 11)		
12 A cooperative demonstration in the establishment of new seedings (Department of Farm Crops)	4	500
13 A cooperative demonstration in the establishment of alfalfa (Department of Farm Crops)	4	500
14 A cooperative demonstration of the value of commercial fertilizer for top-dressing old meadows (Department of Farm Crops)	3	500
15 Courses in forestry at Cornell (Department of Forestry)	13	5,000
Total	42	27,000

*Supplements not included, as printed with lessons.

	Number of pages in printed bulletin	Number of copies printed
MISCELLANEOUS:		
Dean's report to President	44	27,000
Report of the Dean of the New York State College of Agriculture (Separates)	25	500
Handbook of information for students in agriculture	32	1,200
Total	101	28,700

NEWS ITEMS:
One hundred and forty-nine news items were issued, with an aggregate circulation, according to actual clippings received, of not less than 28,179,297.

SUMMARY

	Total number	Total pages	Copies printed
Experiment station bulletins	11	490	215,000
Experiment station memoirs	4	436	26,500
Experiment station circulars	6	80	117,000
Reading course lessons for the farm	12	322	*635,000
Reading course lessons for the farm home	12	326	*615,000
Rural school leaflets	4	444	655,000
Annual report	1	2,631	2,000
Announcements	2	116	27,000
Farm bureau circulars	2	108	14,000
Extension circulars	7	42	27,000
Miscellaneous	3	101	28,700
Total	64	5,096	2,362,200
News items 149, circulation 28,179,297.			

* Supplements not included in number of copies, as printed with lessons.

BRISTOW ADAMS,
Professor of Extension.

DEPARTMENT OF FARM MANAGEMENT

TEACHING

The Department of Farm Management offered for the first time this year a course in the third term. The enrollment for the year was as follows: first term, 379; second term, 328; third term, 31; winter course, 254; total undergraduate enrollment 992, an increase of 44 over the figures for the preceding year; graduate students, 19.

EXTENSION

In cooperation with the United States Department of Agriculture, farm efficiency demonstration work was begun in the past year. An assistant professor and an instructor have cooperated with the county agents in obtaining financial records of farms in 16 counties. The work for the year is summarized for each farm, and the results are returned to the farmer with averages for other farms in his region and suggestions for possible improvement based on the ways in which his farm differs from the average and from the more successful farms. The records thus far used are as follows:

County	Number of records	County	Number of records
Nassau	84	Allegany	92
Ulster	78	Chautauqua	231(?)
Dutchess	68	Niagara	185
Clinton	101	Monroe	106
St. Lawrence	144	Herkimer	71
Jefferson	102	Montgomery	75+
Cayuga	45(?)	Otsego	105
Tompkins	63	Oneida	60
Chemung	129(?)	Cattaraugus	72

One instructor has spent the year in teaching in extension schools and at fairs, and in doing other forms of extension work, and has obtained records from 115 farms in Broome County on the cost of producing milk.

INVESTIGATION

Work on agricultural surveys, and the study of successful farms found by the survey method, have been continued. The cost of producing milk and the cost of producing potatoes have been studied by the survey

method. Cost accounts are being kept on 74 farms in the State. The farm records obtained in the demonstration work will ultimately be of use in investigative work.

G. F. WARREN,
Professor of Farm Management.

DEPARTMENT OF FARM CROPS

The staff of the Department of Farm Crops has been strengthened in the past year by the appointment of O. W. Dynes as instructor, and of John H. Barron as assistant professor in charge of extension teaching and demonstration work.

TEACHING

Through the appointment of an instructor and of additional graduate assistants, the Department has been able this year, for the first time, to offer advanced work. The undergraduate work has also been considerably improved. The number of undergraduates registered was 319, of whom 32 were for the summer term; the graduate students numbered 14.

INVESTIGATION

The classification of American varieties of oats has been completed and is ready for publication; progress has been made toward similar work on barleys and wheat. Work on the legumes has been discontinued because of lack of funds. The principal lines of study with silage corn, forage grasses, and rotation experiments, have been continued without change.

EXTENSION

The appointment of Assistant Professor Barron has enabled the Department for the first time to take part in the extension activities of the College. In addition to work in the demonstration schools for four months, Professor Barron has started some three hundred cooperative demonstrations with farmers, which are usually carried on in cooperation with the farm bureaus, and most of which are planned to follow up the work of the demonstration schools. Other members of the staff have assisted at several county fairs, on two demonstration trains, and at various other meetings.

E. G. MONTGOMERY,
Professor of Farm Crops.

DEPARTMENT OF FARM PRACTICE

The requirement of the College as to the farm experience necessary for its students led to the appointment, in the past year, of Professor A. C. King to take charge of the students' farm practice records, the placing of students on farms, and the giving of elementary instruction in farm practice so that when students are placed on farms as helpers they can more readily make themselves useful to their employers. Professor King took up this work on April 1. The aim has been, not to materially change the work previously done or the manner of doing it, but to more thoroughly systematize it, to develop the details and perfect the records so as to have the data more readily available, to do more follow-up work, and especially to provide more facilities and help for giving instruction and practice in very elementary farm work on the college farm.

The plan is to provide practice for one period each week throughout the year, without university credit, to 75 freshmen by assignment. This is designed to train city boys in fundamental farming operations, so that they will be of more value to the men to whose farms they go for further practice. At the present time the Department has records and is following the work of 170 students and 15 prospective students who are working on farms in order to gain experience. The Department has also assisted 14 graduates or former students to find places. So far as received, the reports from students and their employers have been in the main satisfactory. It is believed that the closer supervision now being given to students working on farms, in connection with the reports now required from students and employers, will result in greater benefit to the students and in more satisfactory service to their employers.

Aside from the work done by this Department for the University, for the College, and for the various departments, it has conducted active farming operations on 324 acres of land. The area of each crop, and the products, so far as harvested, are as follows:

Crop	Acres	Product
Hay	143	437 tons
Corn silage	46	381 tons
Oat and pea silage	10	81.55 tons
Oat and pea forage	3	20.12 tons
Oats	74	4,336 bushels
Wheat	36	859 bushels
Roots	2	41 tons
Potatoes	10	....
Wheat and oat straw	....	104 tons (approx.)

J. L. STONE,
Professor of Farm Practice.

DEPARTMENT OF PLANT BREEDING

Progress in the work of the Department of Plant Breeding during the past year has been made along two lines, teaching and investigation. Owing to a lack of funds the third line of college effort, extension work, has not progressed as rapidly as the situation demands. While the activities of the Department are organized in a general way into the three groups noted, there is no sharp segregation into wholly separate divisions. The members of the staff primarily engaged in teaching are interested also in one or more of the investigative projects of the Department; likewise the men whose principal work is investigation are all connected with the work of instruction in its graduate phase. There is no one in the Department who is responsible primarily for extension work. While the whole staff is concerned in a way with extension activities, the burden of this work during the past year has fallen on two men whose time is devoted largely to investigation.

TEACHING

Graduate students now consult with the several members of the staff before registering, and all applications for registration are considered in staff conferences. The results of this practice have been to discourage the registration of some poorly prepared men and to encourage further preparation on the part of others. Registrations have been distributed more evenly among the members of the staff, with the result that no one man is overburdened with students, and graduate work can therefore be more carefully supervised.

The better distribution of graduate students, the material increase in funds available for the work of instruction, and increases in staff for undergraduate teaching, have made possible some reorganization of courses, the addition of new courses, and greater efficiency in general.

The number of undergraduate enrollments during the past year was as follows: first term, 253; second term, 60; third term, 40; summer school, 13; winter course, 28; total (including duplicate enrollments), 394. The graduate students numbered 35.

INVESTIGATION

RESEARCH UNDER THE ADAMS ACT

Notable progress has been made in studies of the inheritance of characters in crossbred corn, wheat, oats, barley, and morning glories. Material has accumulated for similar studies of beans, and a beginning has been made in hybridizing potatoes.

Second and third generations of many small-grain hybrids have furnished material for a study of the inheritance of the various characters of these cereals. A number of particularly interesting hybrids have been obtained by crossing the common cultivated oats with wild oats. The results from crossing different species of wheat have given valuable information in regard to the Mendelian behavior of various characters, and are of considerable interest in connection with theories concerning the origin of the cultivated wheats.

Definite advance has been made in the identification of genetic factors concerned in the heredity of characters in corn, the method of inheritance of some twenty pairs of such factors having been determined. A beginning has been made in working out interrelations of these factors. It has been found, for instance, that nine of the factor pairs in corn can be arranged in three groups, the members of each group being inherited more or less together.

The pure-line work with wheat and oats has continued to yield valuable information in regard to the possibility of the inheritance of variations within pure lines. The correlation studies with wheat and oats have been continued in cooperation with the Missouri and Montana experiment stations.

The study of the amount of variation within tuber lines of the common potato has been intensified by reducing the number of lines that are grown and by making more detailed observations on the individuals in the different lines. Offspring of single eyes have been grown for detailed study with especial reference to color variations. The material for the comparison of the apical and basal ends of seed tubers has been considerably increased.

In connection with the bud-variation studies with timothy, vegetative propagations from single individuals have been increased as rapidly as possible and data of a statistical nature have been collected.

RESEARCH UNDER THE HATCH ACT

The improvement of the small grains has been pushed forward rapidly. Many of the older selections and hybrids have been tested further in regard to their yield and other qualities, and the seed of some of these is being distributed for further testing by the farmers. Many new selections of oats have been grown during the past year, and some of these have given indications of being very good in yield and of producing strong straw. A large number of new head selections of oats were grown for the first time; the best of these will be continued in further tests. In addition to these selections, many hybrids between sorts possessing desirable characters have been further purified in preparation to making yield tests. In the work with wheat, also, numerous selections have

given promise of a high yield coupled with good winter-resistant qualities. Over sixteen hundred new selections have been made from wheatfields in various parts of the State, and are under test with a view to improving the type of wheat now grown.

Coupled with the regular variety test of these sorts and the study of the ability of the various ones to yield well, notes are also being taken in regard to disease resistance, winter resistance, and many other characters.

In the study of methods of breeding potatoes, the efficacy of hill selection has been further confirmed by the results of another year. Good-yielding strains that have been isolated are now being propagated by mass selection in order to determine how long they will continue to hold up without hill selection. New stock has been brought in and new selections have been made for the purpose of producing better strains for general use.

In connection with the timothy work, the comparative testing of new varieties has been increased so far as land is available. Closely inbred and crossbred seed from the same varieties has been sown this year for purposes of comparison.

EXTENSION

Various activities of an extension nature have been engaged in during the past year, including participation in field meetings and demonstrations, help in conducting a potato train, exhibition of illustrative material at the State Fair, and the like. Help has also been given to a few farm bureau agents and to several farmers in planning and carrying out practical breeding work with corn, wheat, oats, potatoes, and cabbage. Seed of improved wheat, oats, corn, and timothy, from the Hatch experiments, has been distributed to farmers in various sections of the State. In so far as possible the Department has kept in touch with the men who have received this seed, with the aim of assisting in wider distribution of that which has proved valuable.

R. A. EMERSON,
Professor of Plant Breeding.

DEPARTMENT OF BOTANY

TEACHING

The total amount of instruction given during the past year shows a substantial increase over that of the preceding year. New courses were given in histology and cytology, and a course in lichens, mosses, liverworts, and ferns was given in the summer session. The introductory course in general botany was given for the first time as a one-semester course. Owing to lack of facilities, the registration in this course was limited to 338 students. The introductory course in plant physiology showed a marked increase in registration.

The enrollment for the year was as follows: first term, 410; second term, 248; third term, 58; summer session, 120; total undergraduate registration, 836; graduate students, 57.

At the beginning of the year, J. K. Wilson, instructor in plant physiology, was appointed assistant professor of soil technology. A. J. Eames was promoted from an instructorship to an assistant professorship, and L. W. Sharp and J. Rosenbaum were appointed instructors.

INVESTIGATION

The number of persons engaged in investigation during the year, including members of the staff and graduate students, was approximately thirteen. Owing to the large amount of time required for the instructional work of the Department, but little progress in research has been made during the year.

EXTENSION

The extension work of the Department has been confined to three lines of work, as follows:

1. Correspondence with farmers and others in regard to weed identification, weed extermination, legume inoculation, and like matters. Letters relating to weeds numbered 280; those relating to legume inoculation amounted to 2200.

2. The supplying of cultures containing organisms for inoculation of the soil in preparation for leguminous crops. Cultures were sent to farmers of the State, on request, at a nominal price to cover the cost, the number of cultures distributed being 7025. This work has increased so rapidly as to overtax the facilities of the Department.

3. Lectures and demonstrations. Lectures on legume inoculation were given in Farmers' Week in February. An exhibit of legume inoculation was shown at the College during Farmers' Week, and at the State Fair

in September. An exhibit of several hundred weeds growing in New York State was shown during Farmers' Week.

RECOMMENDATIONS

The principal needs of the Department are as follows:

There should be at least three more laboratories — two capable of accommodating twenty students in general botany, and one for a section in plant physiology.

The staff should be increased by at least three assistants or instructors.

There is need of more office space, and also more space for herbarium, laboratory material, and other collections. Every available corner is now filled and expansion is impossible.

A conservatory should be provided, to contain illustrative material to be used in class work. Such plants must be available in the classroom during cold weather.

A small botanical garden is needed, in which could be found at least the common illustrative material used in instruction in botany.

K. M. WIEGAND,
Professor of Botany.

DEPARTMENT OF PLANT PATHOLOGY

TEACHING

In the Department of Plant Pathology much time has been given in the past year to revision of the regular courses and to the collection and preservation of new material for illustrating the work. The total number of students registered in the various courses shows an increase of 72 over that of the preceding year, the increase being mainly in the general introductory course. There were 25 graduate students registered in the Department.

INVESTIGATION

Of the eighteen distinct lines of investigation reported last year, nine have been carried along and are to be continued. These are the studies of bean anthracnose, truck diseases, forest tree diseases, apple tree canker, diseases of gladiolus, cereal smuts and their control, and diseases of the peony; mycological researches; and environmental studies. The remaining nine problems have been discontinued or completed.

The following new lines of investigation have been undertaken during the year:

Root diseases of beans.— An investigation of some bean diseases of obscure origin has been undertaken. The work is made possible through the financial cooperation of the Bean Growers' Association of the Wyoming County Farm Bureau. At least two pathogenic fungi have been definitely connected with the diseases.

Cabbage diseases.— An investigation of the diseases of cabbages in the State of New York, especially the club root disease, has been undertaken. The chief aim is to ascertain some of the difficult and unknown facts in the life history of the pathogene, and to perfect a more satisfactory method for the control of the disease.

Mycological researches.— A number of mycological studies have been undertaken by different members of the staff on various parasitic fungi attacking wild and cultivated plants. These studies are in the nature of life history, cytologic work, and taxonomic work.

The fungous flora of timothy and other grasses.— A long-time investigation has been begun for determining the relation of pathogenic fungi to reduced yields and crop failures of grasses and crop plants.

Potato diseases.— Investigations of potato diseases have been undertaken, especially on the necrosis and the wilt diseases as they occur in the State of New York.

VEGETABLE DISEASES.— By a cooperative arrangement with Rochester University, investigations of vegetable diseases have been undertaken. The work is being done in the biological laboratories of Rochester University and in adjacent greenhouses in the Irondequoit section. The studies have to do largely with the diseases of greenhouse cucumbers, tomatoes, and celery.

PEACH YELLOWS.— An investigation into the etiology of peach yellows has been undertaken.

CEDAR RUST.— A careful study is being made of the life history of the local species of the genus Gymnosporangium, producing cedar rust. Some of these species are very destructive to pomaceous fruit in some sections.

EXTENSION

In the past year, 184 places, representing 112 localities in 26 counties, have been visited, as compared with 186 places, representing 126 localities in 30 counties, visited the preceding year. Of these 184 visits, 75 were made at the request of or in cooperation with the farm bureau managers.

Lessons on plant diseases have been given at extension schools held at six places in the State.

Demonstration meetings have been held in different parts of the State for the purpose of demonstrating control of oat and wheat smut, treatment of seed potatoes, preparation of bordeaux mixture, spraying and dusting apple trees, spraying potatoes, rouging of potato diseases, and dusting for control of hop mildew. The dusting of hops for mildew was continued under a special extension project for the control of plant diseases by spraying and dusting. Comparative potato spraying experiments have been conducted in two counties.

Aside from the exhibits annually shown at the fruit growers' association meetings and the State Fair, exhibits have been made at county fairs and at other meetings of fruit growers. Thirty lectures on various phases of plant disease work have been given by members of the staff at farmers' institutes, horticultural society meetings, clubs, granges, and other meetings. In addition to these, twenty-four lectures have been given in connection with the potato special and farm train run over the New York Central lines.

Many inspection trips have been made, largely in cooperation with county agents and potato growers' associations, looking to the raising of the standard of seed potatoes shipped from different localities of the State.

In the past year 4677 letters have been written, as compared with 3245 written the preceding year. A large proportion of these were in response to plant disease inquiries.

PUBLICATIONS

Publications of the Department aside from those issued by the University, which are listed elsewhere, are as follows:

A parasitic species of Claudopus. By H. M. Fitzpatrick. Mycologia, vol. 7, p. 34–37.

Dusting the apple orchard. By Donald Reddick and C. R. Crosby. Proceedings of the New York State Fruit Growers' Association, 1915, p. 67–75.

Serious diseases of the past season. By Donald Reddick. Proceedings of the Western New York Horticultural Society, 1915, p. 78–81.

Diseases of the peony. By H. H. Whetzel. The American Florist, April 10, 1915.

Diseases of the peony. By H. H. Whetzel. Transactions of the Massachusetts Horticultural Society, 1915, p. 103–112.

Impressions I received of plant diseases and their control in Europe. By H. H. Whetzel. Proceedings of the New York State Horticultural Society, 1915, p. 63–67.

Illustrated talk on experiences in Europe. By H. H. Whetzel. Proceedings of the New York State Fruit Growers' Association, 1915, p. 122–127.

RECOMMENDATIONS

Although the Department is about as comfortably housed as it can be in its present quarters, these quarters are inadequate for the type of work that is to be done, and it is hoped that an adequate and satisfactory building may soon be made available.

The present instructing staff is not sufficiently large to handle the work of the Department. It is recommended that provision be made for one additional assistant professor, one additional instructor, and one additional assistant. If the research problems of pressing importance in the State are to be met adequately, there must be an increase also in the number of members of the staff for investigative work. At least one additional assistant professorship and one or more positions with the grade of instructor should be created for this field.

While one assistant professor has been added to the extension staff during the past year, made necessary by the new extension project in spraying and dusting demonstrations, this does not provide for the rapid growth and development of the regular extension work now in hand. An additional assistant professor is much needed for proper conduct of the work. In fact, so insistent has been the demand for extension work from this Department that the professor in charge of the field has found it imperative to devote most of his vacation period to extension work throughout the State.

The present location of the Department, in the basement of Bailey Hall, affords no satisfactorily lighted place for the taking of photographs, for which there is a large demand in connection with plant disease investigations. It is urgently recommended that some provision be made for this need.

While the present facilities for field experiments are inadequate to the needs of the Department and will probably always remain more or less so, it is thought that the addition of a small plot of ground directly to the rear of the new greenhouses assigned to the Department would materially relieve this condition. If, however, the investigative problems now under way, and new ones that should be undertaken, are to be properly conducted, considerable additional field space is required. In view of the importance of the fruit interests in the State, and the heavy demands made on the Department for investigation of the diseases of fruit crops, it is urged that a sufficient tract of land somewhere on the farm, well removed from the present orchards, be set aside for orchard plantings for the special study of plant diseases.

H. H. WHETZEL,
Professor of Plant Pathology.

DEPARTMENT OF SOIL TECHNOLOGY

The completion of Caldwell Hall has provided the Department of Soil Technology with convenient and well-equipped quarters. The building is 134 feet long and 40 feet wide. In the basement are the laboratory for introductory courses and the stock rooms for supplying the students working there, also the machinery for the water supply, the ventilators, the elevator, and the water still, and a vault for permanent storage of soil and other samples collected in the course of the Department's investigations. On the first floor are a large lecture room, offices for the extension work of the Department, and one main office for the undergraduate instructional work. The second floor provides accommodations for the Departments of Rural Education and Rural Engineering. For the joint use of the latter and the Department of Soil Technology there is a large drafting room, used by this Department for soil mapping and drainage work. On the same floor is the laboratory for mechanical soil analysis. The laboratories for research and for the graduate students are on the third floor. The attic is used for such operations as preparing and grinding samples, for repairs, and for photography, and also for some of the graduate students, not all of whom can be accommodated on the third floor.

TEACHING

Eight courses of instruction, in which were registered 610 students, were given during the year. Three of these courses were given in the third term. The registration in the general course for the third term was 25; in the first and second terms the registration for this course was 118 and 145, respectively.

In the total registration for all courses there was a slight decrease from the previous year, which is possibly to be accounted for by the discontinuance of a course in manures and fertilizers given formerly.

Nineteen graduate students were registered for major and minor subjects in the Department.

INVESTIGATION

The first five-years period of experimentation with the soil tanks has been completed and the results are being compiled.

SOIL SURVEY

A soil survey of Schoharie County has been completed this year, and the survey of Cortland County has been begun.

EXTENSION

Instruction in soil technology was given in twenty-one extension schools during the winter of 1914–15. Educational exhibits were shown at the

State Fair, at one local fair, and on one farm train. Advice and services in the drainage of farm land have been given on 25 farms. Twenty-three lectures have been given at farmers' meetings outside of Ithaca, and ten lectures were delivered at the College during Farmers' Week. Correspondence was about the same as last year, amounting to about 4000 letters sent out.

PUBLICATIONS

Publications of the Department aside from those issued by the University, which are listed elsewhere, are as follows:

Soil problems of the florist. By E. O. Fippin. The American Florist, vol. 43, no. 1372, p. 457–461.

Muck soils in New York. By E. O. Fippin. New York State Department of Agriculture, Bulletin 70, p. 1238–1246.

The principles of soil management. By E. O. Fippin. Proceedings of the Agriculture Society of South Carolina, 1915, p. 1–12.

Fertilizer problems for potato growers in 1915. By E. O. Fippin. Proceedings of the New York State Potato Association, 1914.

Studies in the drying of soil. By M. A. Klein. Journal of the American Society of Agronomy, vol. 7, p. 49–77.

The formation of nitrates in soils under grass. By T. L. Lyon. Proceedings at the Sixteenth Annual Meeting of the Western New York Horticultural Society, p. 82–87.

A comparative study of the effect of cumarin and vanillin on wheat grown in soil, sand, and water cultures. By J. Davidson. Journal of the American Society of Agronomy, vol. 7, p. 145–158, 221–238.

RECOMMENDATIONS

It is desirable that an expert in soil survey, who will be a permanent employee, be engaged, in order to give continuity to the work. At present this work is done entirely by students who seldom serve for more than two consecutive summers.

It would add much to the knowledge of the soils of the State if a series of experiment plats were established on different soil types. Such a series of plats would serve for use by both this Department and the Department of Farm Crops.

Plans for the development of the ranges of glasshouses involve the removal of the old house now used by the Department. As this house is a very essential part of the laboratory equipment of the Department, it is recommended that provision be made for building another house before the old one is removed.

T. LYTTLETON LYON,
Professor of Soil Technology.

DEPARTMENT OF POMOLOGY

TEACHING

The enrollment in the Department of Pomology for the past year was: first term, 390; second term, 452; third term, 71; winter course, 169; summer school, 36; graduate students, 26.

INVESTIGATION

Investigations have been under way on variety tests, the value of selected scions, pruning old and young trees, tree planting, hardiness studies, fertilizers for strawberries and bush fruits, influences that affect the setting of fruit, and factors influencing the color of fruit.

The irrigation experiment has been dropped. Experience has indicated that no data of value are likely to be obtained within a reasonable length of time because of the variability of the seasons, and the increase in yield from irrigation is nearly always within the range of experimental error.

As the departmental orchards come into bearing, experimental work in the grading and marketing of apples is done. An effort is being made to learn whether or not the increased prices that result from grading apples according to size are sufficient to offset the cost of such grading.

In addition to the study of the osmotic relationship and incipient drying of the fruit, pruning experiments have been undertaken to determine the influence of the different pruning systems on the efficiency of the leaves in photosynthesis, and to determine whether or not there is a marked difference in the amount of dry matter produced by the same leaf surface in different varieties.

EXTENSION

The extension activities of the Department for the past year have comprised 16 lectures, 52 demonstrations in pruning, spraying, and packing, 17 inspections, 7 demonstration schools, 5 exhibits at the State Fair and at county fairs, and 16 miscellaneous enterprises. In addition, the Department cooperated with the New York Central Railroad and the State Department of Agriculture in the operation of an apple packing train through the fruit sections of the State for a period of three weeks. Stops were made at 38 places and the total attendance was 2751.

New extension work undertaken consists of a demonstration variety test of strawberries for canning purposes, at Webster, New York; a demonstration of the value of certain commercial fertilizers in the growing of strawberries, at North Collins, New York; and a demonstration of the methods whereby an old and neglected orchard may be profitably renewed, at Port Byron, New York.

RECOMMENDATIONS

The Department is in need of a cold storage plant. As the young experimental orchard develops, the cost of maintenance will greatly increase. Satisfactory returns from the orchard cannot well be secured without some sort of storage equipment. Further, it is desirable that the Department should conduct experiments to determine the killing temperature of various plants and fruits in storage, and for such work a room in which the desired temperature can be maintained is necessary.

It is understood that the old barns on the Bool farm are to be removed. This will leave the Department with no room for packing fruit or for storing machinery. An adequate packing shed is needed, both for these purposes and for giving instruction in packing.

The Department has no greenhouse space. Some specimens of exotic fruit plants should be kept in a conservatory, for use in teaching the course in systematic pomology. A place is also needed where ordinary deciduous plants can be grown for special purposes in demonstrating lectures. It is believed that it would be advantageous for all the plant industry departments if a large conservatory could be maintained under the direction of some one department, such as Floriculture. In this way the cost would be much less for the relatively small amount of material needed by some departments than if each department maintained a separate room for such purposes.

The Department needs also a small amount of greenhouse space in which to conduct a thorough study of the root growth of trees and bush fruits, particularly as influenced by different methods of pruning and fertilizing, and for other experimental work.

W. H. CHANDLER,
Professor of Research in Pomology.

DEPARTMENT OF FLORICULTURE

Investigation has been carried on by the Department of Floriculture, during the past year, with peonies, sweet peas, gladioli, roses, phlox, asters, aquilegias, and iris. The peony studies are practically finished. The peony collection forms a basis for study by the students and is of interest to visitors.

About 150 tests have been made with sweet peas. Some of these tests were on forcing varieties and some on out-of-door varieties. The Department is endeavoring to obtain a complete collection of waved forms for study.

Only a very few new varieties of gladioli have been received this year, and it is therefore believed that the work with this group is now practically complete. Material for two bulletins has been prepared and will soon be offered for publication.

The investigative work of the Department has centered largely in rose studies, and the rose garden established a year ago has been developed. The number of varieties in this garden is now approximately 475. An extensive collection of wild rose species has been received from the Arnold Arboretum. The problems in rose culture that confront the Department are, to determine practical means of winter protection, and to construct some system for watering the plants. Stock for spring planting is often received so late that heat and drought make it difficult to care for the plants properly. It is recommended that the Skinner system, for which a project has already been developed, be installed.

At the present time there are 513 plantings in the phlox field. Studies have been made on the different plants to determine how many varieties are synonymous.

Several thousand aquilegias, the result of the crossing of varieties and species, have been planted.

Investigations with iris are under way. Many varieties have been received from iris specialists, and have been planted on the area assigned to the group.

The perennial border contains a good collection of species. All surplus plants of peonies, iris, and other perennials have been removed to a separate area so that they may be utilized for the production of cut flowers for class work and other purposes. This arrangement makes it possible to obtain material without interfering with plants under experiment.

In the instructional work, two new courses have been given: one in the history and literature of floriculture, the other in marketing flowers

and plants. Student registration in the Department was larger this year than ever before.

At the request of the Dean, the development of the project for the erection of new greenhouses for all departments was undertaken by the head of the Department of Floriculture. The range is now practically complete and the departments interested feel that they have an equipment adequate for their work. The Department of Floriculture, however, feels the need of an additional range especially adapted for investigative work, and it is hoped that the project for such a range may be developed in the near future.

Early last spring a committee appointed by the Dean to investigate the housing of various departments arranged to finish the second floor of the floriculture building so that a classroom, a reading room, and offices for the instructors would be available. This has been found a great convenience. It is especially desirable to have a classroom for teaching floricultural subjects closely connected with the greenhouse areas. It is hoped that in the near future provision may be made for adequate office and laboratory space for the entire Department, in some central location.

The Department was represented this year for the first time at the exhibit in connection with the International Flower Show in New York City, March 17 to 23. It has also been represented at various fairs in the State and at garden flower competitions. The staff has responded to various calls for outside lecturers, and lectures on floriculture were given in Farmers' Week. Two public exhibitions were held, at which the attendance was large. These exhibitions seem to be valuable educational features of the work of the Department.

E. A. WHITE,
Professor of Floriculture.

DEPARTMENT OF VEGETABLE GARDENING

TEACHING

This year is the first in which the course in commercial vegetable gardening for students specializing in the work has been given in the second and third terms, instead of in the first and second. The number of students registered was not large, but the advantages of the new plan were evident on every side. On the whole, the policy of conducting the courses for specialists in conformity with the growing season rather than with the academic year is meeting with most encouraging interest, both on the part of students and on the part of growers and of other institutions.

The laboratory work is seriously handicapped through lack of space for class assignments and for demonstrational plantings. The area of sandy soil at East Ithaca, consisting of 3½ acres, is much overcrowded. Additional land must be provided if the increase in number of students is to continue. The gardens are now showing in high degree the effect of the special attention which has been devoted to the improvement of fertility. They have been kept in much better condition this year than in any previous season.

EXTENSION

A series of demonstration trials to show the influence of various fertilizer materials on late cabbage has been established on each of 11 farms, and duplicated on the university farm.

The development of demonstration work during the growing season, and of extension school and lecture work during the winter, is making it more apparent that additional help will be necessary for this branch of the departmental activity.

INVESTIGATION

The muck land experiment established in 1912 at Canastota and at Clyde has been continued. Other cooperative trials have been conducted on Long Island, in western New York, and in greenhouses at Elmira.

At the College, studies of the types and varieties of celery and radishes have been undertaken, and also a study of the fertilizer requirements of the tomato.

RECOMMENDATIONS

For some time definite action for the benefit of the vegetable producers of eastern Long Island has been contemplated. A greater or less amount of superficial work has been done, but the need is for a thoroughgoing study of agricultural conditions in this important district.

The interest in vegetable gardening in connection with schools is increasing in marked degree. A course for teachers of this subject was given in

the summer school. There seems to be little question that of all the forms of agriculture, vegetable gardening is best adapted for use in secondary education. The Department is in need of a man to take up this junior extension work.

Research activity, which is thoroughly fundamental and which is carried on by men giving to it their prime attention, seems to be essential to the proper development of any department. A man who could give his full time to technical, rather than demonstrational, problems in vegetable gardening is urgently needed for both indoor and outdoor work.

The amount of glass available for the Department has been increased from 3700 to 6000 square feet. This amount, however, is utterly inadequate, and the teaching range should be completed as projected at the earliest possible date.

Altogether the year just closed has been most encouraging. The staff is now organized on a thoroughly sound basis, and as its members gain in experience the character of the work constantly improves. While because of restrictions as to prerequisites the number of students is not large, the capacity of the teaching facilities is tested to the full and each year sees a larger number of students who are deeply interested in this phase of agriculture.

PAUL WORK,
Instructor in Vegetable Gardening and Superintendent of Department.

DEPARTMENT OF FORESTRY

This year the Department of Forestry has lost by resignation one professor. F. B. Moody, Extension Professor of Forestry, resigned in August to become State Forester of Wisconsin, the resignation becoming effective on September 30.

A considerable supply of instruments, charts, and other illustrative material has been purchased during the year from the building equipment fund, together with some additional equipment and furniture for lecture rooms, laboratories, and offices. The Department has received from two commercial companies a collection of saws and another of various logging tools, for exhibition purposes. These exhibits, properly mounted, are displayed in one of the large laboratory rooms.

TEACHING

Thirty-two courses were given during the year, as follows: first term, twelve; second term, ten; third term, eight; winter course, one; summer school, one. The following table, which includes duplication of students, shows the comparative figures for the past three years:

Year	Registration			
	Graduate students	Regular courses	Winter course	Summer school
1912–13	....	412	47	22
1913–14	40	350	57	28
1914–15	112	436	20	18

The actual number of professional forestry students enrolled with the Department during the past three years has been as follows:

Year	Undergraduate	Graduate	Total
1912–13	42	1	43
1913–14	60	5	65
1914–15	70	14	*84

* Three terms this year.

In addition, 121 nonprofessional students from other departments were enrolled in forestry courses in 1914–15.

Two graduate students received the degree of master in forestry in February, 1915, and four at Commencement in June, 1915. One additional graduate student satisfactorily passed his master's examination in September, 1915.

The giving of forestry courses in the summer term in 1915 proved highly satisfactory. The first six weeks were spent at Ithaca, the last ten in camp on a large forest tract in St. Lawrence County, in the Adirondacks. There were in attendance 15 seniors and 5 graduate students.

EXTENSION

Extension work in forestry consists of (1) woodlot and timberland examinations, made at the request of the owners; (2) cooperation with city water boards and others in planting; (3) lectures and talks before granges, extension schools, farmers' institutes, and other meetings. In addition to personal visits much assistance is given by correspondence. The extension professor devotes one-third of his time to instruction at the College. The cost of all cooperative work is borne by the person who asks for it, but covers only the cost of travel and subsistence.

In the past year 26 woodlots, containing 938 acres, have been examined, and their owners advised as follows: in 6 woodlots advice was given in regard to both forest planting and improvement; in 6, advice in regard to forest valuation; in 5, as to forest planting; in 3, as to forest planting and thinnings to increase growth; in 2, as to improvement cuttings and thinnings to increase growth; in 1, as to forest valuation and forest planting; in 1, as to forest valuation and improvement cutting; in 1, as to improvement cutting; in 1, as to damage from fire. In the preceding year the total area examined amounted to 836 acres, contained in 15 woodlots.

At the request of the owner, the Department undertook the supervision of the planting with forest trees of an area of approximately 15 acres at Solon, New York, in the spring of 1915.

Progress is being made with the several demonstration areas that have been established in different parts of the State with the cooperation of woodlot owners. The purpose of the work on these areas is to illustrate the advantages to be gained from following the best methods of forestry practice.

During Farmers' Week an exhibit illustrative of various phases of forestry work was shown in one of the large laboratories in the Forestry Building, one of the features being a camp showing how foresters live and work in the field. Lectures were delivered also during Farmers' Week by the several members of the staff of the Department.

A forestry section formed a part of the college exhibit at the State Fair at Syracuse in September, 1915.

INVESTIGATION

In the spring of 1915 graduate students, working under the direction of two members of the faculty in cooperation with the New York State Conservation Commission, completed a working plan for a parcel of State land in the Catskill Mountains. The results of a similar project carried on in 1914 were published in the summer of 1915 as Bulletin 11 of the State Conservation Commission, entitled *Forest Survey of a Parcel of State Land*, by A. B. Recknagel.

Experimental forest planting has been continued on certain of the college woodlots, particularly on those known as Behrends and Orchard, and 35 additional acres of the Cornell University reservoir site at Varna have been planted with red pine and white pine.

A forest nursery has been established on Comstock Knoll to replace the nursery on the Bool farm. At present there are 8 seedbeds and about 60,000 seedlings in the transplant rows, the varieties being douglas fir, norway spruce, and white, red, and scotch pine. The new site is much more conveniently located than the former one, and is near the Forestry Building.

Investigations in nursery practice, with particular reference to the use of fertilizers and to the growth and mortality of seedlings, have been continued.

Tests of the relative durability of treated and untreated fence posts are in progress.

Additions have been made to the bibliography of forest organization literature in the University Library.

RECOMMENDATIONS

The Department is in need of a man, of the grade of professor, especially qualified to engage in and conduct research. This work is particularly needed in the directions of wood technology and silviculture. With increasing instructional duties the present staff of the Department is unable to undertake investigations for which there is a real demand. It is recommended that provision be made for the appointment of another professor.

The resignation of Professor Moody has emphasized the need of another man for the extension work of the Department. In the interim before a successor to Professor Moody is appointed, provision has been made for carrying on a part of the extension work by the appointment of C. H. Guise as instructor. With the increasing demands on the time of the extension professor, however, it is clear that the services of a man of the grade of instructor are required permanently. It is therefore respectfully recommended that such an additional member be added to the staff of the Department.

Aside from extension work and investigation, the chief present need of the Department is for a college forest, a tract of several thousand acres,

which shall be under the control of the University, to be used (1) as a forest experiment station, (2) as a demonstration forest, and (3) as a place in which to give students drill in forestry operations under true forest conditions. The Department has been fortunate thus far in obtaining the cooperation of owners of large tracts of forest land for its field work in the third term and at other seasons, but as a permanent arrangement such a policy is open to grave objections. Both the former and the present head of the Department have already urged the necessity of a Cornell college forest. This recommendation is respectfully repeated, with added emphasis.

RALPH S. HOSMER,
Professor of Forestry.

DEPARTMENT OF ENTOMOLOGY

The work of the year was begun with Dr. W. A. Riley in charge, and the success of the first year under the changed conditions brought about by Professor Comstock's retirement is largely due to Dr. Riley's diligence and foresight. The Department is fortunate in still having Professor Comstock's presence and council. He is pursuing his own researches with unabated zeal. He goes in and out among the members of the staff, working at his own problems with an unquenchable love for science which is an example to the Department and to the whole University.

The year closes with preparations completed for inaugurating work in apiculture.

A beginning has been made in the transferring of the Department of Vertebrate Zoology from the College of Arts and Sciences to the College of Agriculture. This is in the addition of ornithology, with Dr. A. A. Allen in charge.

This year the British Government sent four Fellows to the College, on the Carnegie Entomological Research Fund. The Department has not had a sufficient number of well-trained men to meet the demand for good positions in other educational and scientific institutions, so that many are called to take positions before they are adequately fitted for the work they will have to do. The chief demands for men come from agricultural colleges, from experiment stations, from other colleges, and from government bureaus.

Much time has been spent during the past year in formulating plans for future work, and in preparing data for the use of the architect in planning a new building for the Department. The data accumulated have been delivered to the State Architect at Albany for his use in drawing preliminary plans.

TEACHING

This year some courses in the Department were given in the third term. The excellent opportunities afforded at this time for field work demonstrated the advantages of a summer term.

The 32 courses listed in the college announcement were all given this year to large classes. The total number of students registered in the Department was 2861, including 59 graduate students, 104 in the winter course, and 145 in the summer session.

INVESTIGATION

All members of the staff and the graduate students in the Department are devoting themselves as fully as possible to the investigation of prob-

lems in the field of entomology. Much of the work listed in the report of the Department for 1914 has been completed; some of this, however, is of such a nature as to require study for some years. The following economic problems have been recently undertaken:

1. A biological and ecological study of the lesser migratory locust, with an investigation of methods of control. This work has progressed so satisfactorily that the results are now being prepared for publication.

2. An extended investigation of the insects injurious to clover. This study will extend through a period of several years. Substantial progress has been made in the study of the clover-leaf weevil and the clover-seed midge.

3. A study of the life history and habits of the cherry leaf beetle. A serious outbreak of this pest occurred in different parts of the State during the past season, calling for investigation by the Department. This investigation has been carried out and the results are nearly ready for publication.

4. A careful and extended investigation of the injuries caused by various insects to the fruit of the apple. This work has proved to be of very great importance, especially since the enactment of the Sulzer apple law requiring the grading of apples. The study has been carried on in cooperation with the Genesee County Fruit Growers' Association, and an extraordinary amount of data has been obtained.

5. A careful and extended study of insects injurious to hops. For the past three years this work has been carried on mainly in the field, in cooperation with hop growers. Many valuable facts have been learned, especially regarding the hop-vine borer. New points in the life history of this insect have been discovered which will have an important bearing on its control. A new pest of hops, the hop redbug, has been studied in detail, and its life history worked out together with methods of control. Other pests have been studied in the same thorough way.

6. A biological study of the pine leaf scale. This pest of the pine has been studied in detail during the past two seasons, and its life history and the means of its control have been satisfactorily determined.

7. An investigation of methods of control of the poplar and willow borer, together with a study of its life history and habits. This insect, which injures poplar and willow trees, especially in the nursery, and for which heretofore no method of control was known, has been carefully studied, and effective means of preventing its injuries have been discovered.

8. A careful and detailed study of the life history of two species of apple aphides. The green apple aphis and the rosy apple aphis, two of the worst pests of the apple, have been studied during the past two seasons with great care and thoroughness. The number of generations and the

length of each have been determined, and the supposition that the rosy aphis lives on plantain during the summer has been confirmed. Experiments in the control of these two aphides have been carried out in conjunction with fruit growers, with promising results.

9. An investigation of the life history and control of the fruit-tree leaf roller. For the past three years rather extended investigations have been in progress regarding this insect. These investigations have now been brought to a close and the results are ready for publication.

EXTENSION

A large part of the extension work in entomology has been conducted in cooperation with farm bureau managers. These men have an intimate knowledge of the problems in their respective counties, and are thus able to save the representatives of the College much valuable time by bringing them quickly in touch with persons who desire assistance. Much of the aid given is in the nature of consultation, in which the representative of the College determines the cause of the injury, gives the necessary information for its prevention or control, and leaves with the farm bureau manager instructions for helping the growers to put these recommendations into practice. In many cases formal demonstrations have been arranged through the farm bureaus, particularly in the control of certain onion insects and in the dusting of orchards.

This Department has also cooperated with the Department of Plant Pathology in conducting a series of demonstrations showing the comparative value of dusting and spraying in the control of apple insects and diseases. Five orchards were used for this purpose, located in a line reaching from Niagara County to Rensselaer County. Four applications of dust and spray were made to trees in each orchard, and the results were carefully checked at picking time. At one of these demonstrations more than two hundred fruit growers were present.

Effective and permanent results have been obtained through teaching at farm demonstration schools, where the instructor has an opportunity to go over the subject of insect control rather thoroughly and to take up with the growers their special local problems, thus helping them to adapt general control principles to their particular needs.

An exhibit of injurious insects has been shown at the three large meetings of the state horticultural societies and at the larger agricultural fairs. In each case a representative of the Department was in charge of the exhibit in order to answer questions asked by the growers.

A series of reading-course lessons on injurious insects and their control is in preparation. The first number, dealing with insects injurious to the fruit of the apple, has already appeared.

PUBLICATIONS

Publications of the Department aside from those issued by the University, which are listed elsewhere, are as follows:

The neotropical Tipulidæ in the Hungarian National Museum (Diptera). IV. By C. P. Alexander. Entomological News, vol. 25, p. 351–363.

New or little-known crane flies from the United States and Canada. Tipulidæ, Diptera. By C. P. Alexander. Proceedings of the Academy of Natural Science, 1914, p. 579–606.

A second bromeliad-inhabiting crane fly (Tipulidæ, Diptera). By C. P. Alexander. Entomological News, vol. 26, p. 29–30.

Description of new species of crane flies from Central America. By C. P. Alexander. Proceedings of the United States National Museum, vol. 48, p. 441–444.

New exotic Tipulidæ (Diptera). By C. P. Alexander. Canadian Entomologist, vol. 47, p. 79–83.

The biology of the North American crane flies (Tipulidæ, Diptera). III. The genus Ula Haliday. By C. P. Alexander. Pomona Journal of Entomology and Zoology, vol. 7, p. 1–8.

A new nearctic Gonomyia (Tipulidæ, Diptera). By C. P. Alexander. Entomological News, vol. 26, p. 170–172.

On a collection of Javanese crane flies in the United States National Museum. By C. P. Alexander. Proceedings of the United States National Museum, vol. 49, p. 157–193.

The biology of the North American crane flies (Tipulidæ, Diptera). IV. The tribe Hexatomini. By C. P. Alexander. Pomona Journal of Entomology and Zoology, vol. 7, p. 141–158.

On the trail of the evening grosbeaks. By A. A. Allen (joint author). Bird Lore, vol. 16, p. 429.

On the Paramo of Santa Isabel. By A. A. Allen (joint author). The American Museum Journal, vol. 15, p. 3.

Plant notebook. By Mrs. A. B. Comstock. September, 1915.

Women beekeepers. By Mrs. A. B. Comstock. Country Gentleman, vol. 80, p. 73.

Insecticides. By C. R. Crosby and R. Matheson. *In* Standard Cyclopedia of Horticulture, p. 1042.

An insect enemy of the four-lined leaf-bug (Poecilocapsus lineatus Fabr.). By C. R. Crosby and R. Matheson. Canadian Entomologist, vol. 47, p. 181.

Catalogue of insects. By C. R. Crosby and R. Matheson (joint authors). *In* Standard Cyclopedia of Horticulture, p. 1047.

The rhododendron lace-bug, Leptobyrsa explanata Heidemann. By C. R. Crosby and C. H. Hadley. Journal of Economic Entomology, vol. 8, p. 409.

The fish notebook. By G. C. Embody.

Fish meal as a food for trout. By G. C. Embody. Transactions of the American Fisheries Society, vol. 44, p. 57–60.

Insects injurious to the household and annoying to man. By Glenn W. Herrick.

Insects of economic importance; outlines of lectures in economic entomology. By Glenn W. Herrick.

Vegetable insects. By Glenn W. Herrick. Report of the New York State Vegetable Growers' Association, 1913–14, p. 180.

The pupal instar of the fruit-tree leaf-roller (Archips argyrospila). By Glenn W. Herrick and R. W. Leiby. Canadian Entomologist, vol. 47, p. 185.

Genera of Plancton organisms of the Cayuga Lake basin. By O. A. Johannsen and J. T. Lloyd.

Handbook of medical entomology. By O. A. Johannsen and W. A. Riley.

The poison glands of the larva of the brown-tail moth (Euproctis chrysorrhoea Linn.). By C. F. Kephart. Journal of Parasitology, vol. 1, p. 95.

Notes on Hydrophilus triangularis Say. By R. Matheson. Canadian Entomologist, vol. 46, p. 337.

The proventriculus of a Hydropscyche larva. By A. A. Noyes. Pomona Journal of Entomology and Zoology, vol. 7, p. 34.

The biology of the net-spinning Trichoptera of Cascadilla Creek. By A. A. Noyes. Annals of the Entomological Society of America, vol. 7, p. 251.

A note on Rhagoletis pomonella Walsh in blueberries. By W. C. Woods. Journal of Economic Entomology, vol. 7, p. 398.

Biosteres rhagoletis Richmond sp. n., a parasite of Rhagoletis pomonella Walsh. By W. C. Woods. Canadian Entomologist, vol. 47, p. 293.

Notes on Brachycentrus nigrisoma Banks. By J. T. Lloyd. Pomona Journal of Entomology and Zoology, vol. 7. p. 81–85.

Notes on Ithytrichia confusa Morton. By J. T. Lloyd. Canadian Entomologist, vol. 47, p. 117.

Wood-boring Trichoptera. By J. T. Lloyd. Psyche, vol. xxii, p. 17.

Notes on Astenophylax argus Harris. By J. T. Lloyd. Journal of the New York Entomological Society, vol. xxiii, p. 58.

RECOMMENDATIONS

The Department needs more room. Nothing would facilitate its work more than the proposed building for entomology and zoology, and it is recommended that arrangements be made for the construction of this building in the near future. An apiary is needed also.

A fish culture experiment station would enable the Department to do work which would probably lay the foundation for scientific fish culture in this State, and which would certainly accomplish much toward the development of new lines of graduate work.

It is recommended that the taking over of the Department of Zoology from the College of Arts and Sciences into the College of Agriculture be completed as soon as possible. Confusion results from the fact that at the present time students in this College may register without tuition charges for work in ornithology, but not for work in other lines of vertebrate zoology.

JAMES G. NEEDHAM,
Professor of Entomology and Limnology.

DEPARTMENT OF DAIRY INDUSTRY

TEACHING

One new course, ice-cream making, has been added in the Department of Dairy Industry this year. The total registration for all courses was 965.

The twelve-weeks winter course in dairy industry was taken by 113 students. Because of the limited facilities it was necessary to refuse entrance to about 40 of the applicants for this course. Of the students in the winter course in general agriculture, 151 took various courses in dairying.

The growth of the instruction work in the Department during the past eleven years is shown by the following figures:

Year	Registration
1904–05	84
1905–06	108
1906–07	183
1907–08	511
1908–09	557
1909–10	461
1910–11	688
1911–12	764
1912–13	894
1913–14	964
1914–15	965

INVESTIGATION

While the instructional work of the Department leaves but little time for the members of the staff to give to research, such investigations as time will permit are being made. The studies under way are as follows: effect of temperature, lactic acid, and composition, on the coagulation of milk; specific gravity of butterfat in milk from various sources, and its effect on the accuracy of volumetric fat tests and on the character of butter produced; effect of acidity on the keeping qualities of neufchâtel cheese; manufacture of camembert cheese; commercial buttermilk; use of formulæ in connection with chemical analyses for determining the percentage of solids in condensed milk products; effect of pasteurization on milk; composition of dairy by-products; incorporation of moisture and salt in butter; the best methods of making cheddar cheese from milk of high acid content; treatment of milk with centrifugal clarifier, for market milk

purposes; effect of low temperature on the bacterial activities of milk; effect of washing curd on quality of cheese, and losses resulting from the process; manufacture of ice cream; influences of different dairy practices on bacteria counts in milk.

EXTENSION

The extension work of the Department consists mainly in cooperation with former winter-course students and others employed in dairying in the State, special attention being given to those who apply to the Department for advice. Assistance is given either by correspondence or by a personal visit, as circumstances require.

W. A. STOCKING, JR.,
Professor of Dairy Industry.

DEPARTMENT OF ANIMAL HUSBANDRY

TEACHING

The registration in the Department of Animal Husbandry for the past year was as follows: first term, 662; second term, 562; winter course, 392; summer school, 44. These figures do not include students taking graduate work in the Department.

A notable addition to the instruction given was a course in slaughtering and the preparation of meats. The registration for this course taxes the capacity of the building to its utmost, and an increase of facilities should be provided.

INVESTIGATION

The investigative work of the Department is very largely continuous in nature and the statistical work is being kept up as for the past several years. A somewhat extended project in cooperation with the College of Veterinary Medicine, looking toward the control of contagious abortion and other troubles incidental to reproduction in the dairy cow, is under way, and also a project along the lines of animal nutrition.

EXTENSION

The extension work during the year has been mainly carried on by one professor who has given his entire time to the work. His services, however, have been largely required at the extension schools, and this has failed to meet the demands for instruction in the field of animal husbandry. Members of the instructing staff of the Department have therefore given some of their time to extension. It is recommended that provision be made for meeting the demand for the work without the necessity of calling on the instructing staff to do it.

H. H. WING,
Professor of Animal Husbandry.

DEPARTMENT OF POULTRY HUSBANDRY

In the past year the auxiliary buildings to be used by the Department of Poultry Husbandry exclusively for teaching purposes have been completed. These buildings, costing $25,000, include a service building, a breed exhibition building, a fattening and pigeon building, a pipe-system brooder house, and three laying houses containing thirty-two pens. The occupation of these buildings will overcome a serious handicap which has existed since the removal of the old poultry plant from the campus two years ago.

Progress has been made in the improvement of the poultry farm of 80 acres. The work done includes ditching, fencing, building cinder paths, a general clearing up, and soil improvement. Much additional work of the same nature yet remains to be done.

The estimated value of the permanent and movable equipment of the Department, as shown by the last inventory, is $155,207.47, apportioned as follows: buildings, $128,475.74; stock, $4848.50; movable equipment and appliances, $13,306.02; land, $7775; miscellaneous, $802.21.

The stock consists of seventeen varieties, of which 1257 individuals are kept for instructional purposes and 1215 for investigative work — a total of 2472 fowls, as compared to 2583 for the preceding year. Approximately 5000 chickens have been reared this year.

It has always been the policy of the Department to employ students or former students whenever possible, on the assumption that a large proportion of the work required is of both educational advantage and money-earning value to the students. The results obtained have fully justified this policy. From the time when the Department was established, in 1903, to the present, 298 students or former students who have taken poultry courses at Cornell have gained experience and financial returns by this means. Among the persons who have become conspicuously successful in the field of poultry husbandry since leaving Cornell are many who found a large measure of self-support and practical education as employees of the Department. An important advantage of the policy is the wholesome atmosphere which is created among students and staff in developing a spirit of democracy and earnestness in service. There are now nine persons working in the Department on this part-time basis.

This year, for the first time, a policy was inaugurated of holding a special meeting of the staff for the purpose of familiarizing the members, the Dean of the College, and other invited guests, with the personnel, method of organization, types of work, and results accomplished. This practice is to be continued.

The total number of letters written by the Department during the past seven years is 57,389. The number of letters written this year is 8623; in addition there were 1449 form letters sent, making a total of 10,072. This is a decrease by 592 from last year, which possibly may be accounted for by the development of the farm bureau county agent project as providing a convenient, efficient, ever-ready source of information in many sections of the State.

TEACHING

The instructional work of the Department is along five lines, as follows:

1. The teaching of regular and special students who desire to specialize in poultry husbandry. In this group nine courses are offered, which provide for 31 hours of university credit.

2. The teaching of regular and special students who desire a practical course adapted to the special needs of the general farmer. The desirability of providing this type of instruction is fully justified by the attendance each year since the course was first given.

The number of regular and special students who took courses in poultry husbandry this year was 326.

3. The teaching of students in the summer school. Among the students who elect the summer courses are those who desire to teach and those who desire to engage in poultry farming. The summer school students this year numbered 33.

4. The teaching of students in the winter courses. These are of two classes — persons who desire to specialize and devote their entire time for twelve weeks to the professional poultry course, and persons who elect farm poultry from other winter courses. The total number of winter-course students this year was 160.

5. Graduate student instruction. Each year an increasing number of persons from this and other educational institutions receive instruction in poultry husbandry. This year there were 11 graduate students. With the increase in teaching facilities made possible by the occupation of the new building, the addition of considerable new equipment, and a larger teaching staff, the Department is now able to offer better opportunities for advanced instruction.

The total undergraduate registration in all courses in the Department for the year was 519.

EXTENSION

The extension activities of the Department include fourteen types of work, as follows:

1. A postal card survey. Through this survey the Department has obtained information of value from 1713 poultrymen in New York State regarding the nature of their poultry farms, the kind and number of fowls

kept, and other data, all of which is graphically shown on a map of the State. This year 243 new surveys have been added.

2. City and village poultry surveys. Surveys have been made in the past year of the villages of Trumansburg, with a population of 1202, and Cherry Valley, with a population of 746, which have furnished valuable statistics regarding the amount of poultry products produced and consumed in country villages. It is expected that the data thus obtained will be published in bulletin form in connection with the poultry survey of the city of Ithaca (population from 15,000 to 16,000) made in 1913.

3. Poultry market survey. Graduate students have made market studies of the quality of poultry and eggs delivered to the Ithaca Poultry Producers' Association, and of conditions in other cities.

4. Poultry farm business organization survey. The Department has made complete surveys of 47 farms. The data thus obtained have been or are being tabulated for use in teaching and extension work. This project will be continued until sufficient data have been accumulated to warrant publication in bulletin form.

5. Pedigree breeding and breed testing. This work, which has been carried on under the name of the Cornell breed testing project, is being continued on as large a scale as the buildings and equipment available will permit, namely, ten flocks of ten fowls each. In this project poultrymen send to the College ten selected females to be trap-nested for one year, the best individuals to be mated to high-pedigree, line-bred Cornell males, the eggs to be hatched, and the chicks leg-banded and sent to the owner.

6. Cooperative poultry marketing. This project has been continued for approximately two and one-half years in the development of the Ithaca Poultry Producers' Association, which is now established on an independent, self-sustaining, profit-making basis. Poultrymen in several localities of the State are considering the organization of similar associations. In the one place outside of Ithaca where an attempt has been made to organize a poultry producers' association — namely, Binghamton — the plan has met with favor, and it is confidently expected that the association will be permanently organized in the near future. Valuable data have been obtained and experience gained which indicate that by proper cooperation poultrymen may expect to receive suitable financial returns.

7. Poultry instruction in rural schools. The boys' and girls' club work in rural schools, conducted in cooperation with the Department of Rural Education, has been increased in the amount of time devoted to it and the number of persons reached. This year 62 places were visited and 188 lectures and demonstrations were given.

8. Demonstration schools, in cooperation with the Department of Extension Teaching. This year members of the departmental staff have

participated in 16 demonstration schools, at which 93 class exercises in poultry husbandry were conducted.

9. Poultry extension activities in Farmers' Week. Each year the Department has given more and more time and effort to assisting Farmers' Week guests. In the last Farmers' Week there were given 58 lectures and demonstrations, with an attendance of 4207; 25 laboratory practice courses, with an attendance of 665; and 8 educational guessing contests, at which 1163 votes were recorded. The total attendance at lectures, demonstrations, and laboratory exercises was 4872, as compared to a total attendance of 4744 in 1914. The plan of giving Farmers' Week visitors an opportunity to obtain actual experience in five handicraft laboratory courses has proved exceedingly instructive and is to be continued.

10. Cooperation with the New York State Fair. The New York State Fair Commission continued this year the policy of providing a large tent in which poultry lectures and demonstrations could be given, and also of setting aside a generous amount of space in the Poultry Building for poultry educational exhibits in addition to the regular allotment of space for this purpose in connection with the regular college exhibit in the Public Institutions Building. This year, for the first time, the State Fair Commission made a special appropriation for the purchase of material for the construction, on the fair grounds, of a full-sized Cornell laying house, which proved to be one of the most attractive teaching agencies undertaken by the Department.

11. Cooperation with poultry organizations. The records of the Department show that there are in the State 99 poultry associations, many of which are more or less inactive. In the past year educational exhibits have been staged in connection with 17 poultry associations, at which 86 lectures and demonstrations were given. The limited number of persons available for extension work in cocperation with the poultry organizations has made it impossible to cooperate as effectively and extensively as the needs of the organizations demand and as the cost and nature of the work would justify. The entire time of one additional extension assistant, and five months additional time of the extension instructor engaged for next year, will make it possible to very materially extend the cooperation of the Department with the poultry organizations and to assist in organizing other associations.

12. Cooperation with farm bureau managers. More and more the farm bureau managers are demonstrating their interest and proving their efficiency in arranging the details for effective cooperation with the poultrymen in their various communities. This relieves the College of a large amount of administrative duty and responsibility in connection with making local arrangements, and still maintains the responsibility of the College for the

subject matter and the methods of teaching, thus proving a highly satisfactory method of cooperation. This type of extension work is capable of great expansion. The value of the work will abundantly justify all the time, effort, and expense that the Department can contribute.

13. Permanent educational exhibits at the College. This year, for the first time, the Department has been able to occupy the large educational exhibit room especially designed for the purpose of keeping on display, for the use of students and visitors, its teaching and extension equipment. The extent to which this educational feature has been utilized abundantly justifies the policy of providing at the College as complete educational exhibits as are provided for similar use away from the College. The display of many of the 1400 lantern slides, charts, models, and photographic enlargements owned by the Department has enabled a large number of persons to derive benefit from the teaching equipment which otherwise would be accessible to them only in the classroom or on extension trips.

14. General extension project. This project is conducted by means of lectures, demonstrations, educational exhibits, reading-course lessons, correspondence, farm visits, and other methods, in cooperation with the Department of Extension Teaching at the College, and with farm bureau managers, officers of poultry associations, Young Men's Christian Associations, granges, county and state fair associations, the New York State Bureau of Farmers' Institutes, and the New York State Fair Commission. The extent to which the Department has carried on general extension activities outside of the College during the year is indicated by the following summarization: number of lectures, 319; demonstrations, 126; educational exhibits staged, 45; farm visits, 356; total, 846. In carrying on this work 373 localities were visited and 14,920 fowls were selected for breeding stock; the lectures and demonstrations were attended by 28,891 persons.

That the extension activities of the Department have grown in volume each year is shown by the number of places visited. These are as follows: for 1909-10, 144; for 1910-11, 164; for 1911-12, 306; for 1912-13, 433; for 1913-14, 584; for 1914-15, 587.

The expense of conducting extension work, in proportion to the number of places visited, the number of persons reached, and the amount of good accomplished, is surprisingly small. The total cost for this work for the year, not including salaries, was $1897.97, of which $440. 89, or 23.23 per cent, was paid from the departmental funds and $494.18, or 26.04 per cent, was paid by the Department of Extension Teaching; private parties and organizations paid $776.37, or 40.90 per cent of the expenses, and the State Department of Agriculture paid $186.53, or 9.83 per cent. It has been exceedingly gratifying to note the willingness with which organizations and individuals have met one-half of the expense, or, in many instances, the entire expense.

INVESTIGATION

Fifteen investigative projects have been conducted in the past year, for which a total of 1215 fowls (1047 females and 168 males) have been used. All these fowls were trap-nested and the chicks were pedigree-hatched and leg-banded. It is estimated that the investigative projects require an expenditure of approximately $5000 a year. The principal problems studied are:

1. The inheritance of fecundity. This study has been continued since 1907, and now includes records of 1124 fowls. At the present time 541 females and 53 males are being used.

2. Inheritance of egg characters. This has been under investigation since 1911, and has included 540 individuals in the breeding flocks. At the present time the study includes 119 females and 71 males.

3. Inheritance of constitutional vigor. This investigation was begun in 1912, and has included, to date, 216 individuals. There are now under observation 80 females and 20 males.

4. A study of conditions influencing constitutional vigor. This project was undertaken in the Department's first year and has received a large measure of attention since that time. Included in these studies are experiments to ascertain the comparative influence of artificial and natural incubation on the vitality of the flocks, and a comparison of close confinement and free-range methods during winter and summer; these questions have been under investigation since 1909, during which time 790 fowls have been recorded.

5. A study of mating behavior as influenced by, or as indicating, constitutional vigor and reproductive power.

The policy of the Department has been to utilize the results of the investigations for teaching and extension purposes as rapidly as reliable data have become available, and to refrain from publication until the questions under investigation have appeared to be conclusively answered.

New devices and appliances, and methods devised by members of the departmental staff, are as follows: a new Cornell trap nest; a measuring caliper for quickly and accurately taking small body measurements of poultry; an improved type of poultry house for egg production; a shadow photographic process for making a correct, permanent outline of eggs, at a greatly reduced cost as compared to the usual photographic method; a set of market poultry instruments; a wind baffler — an automatic, sanitary method of ventilating poultry houses, to displace the muslin curtains or the open front; a labyrinth for use in breeding pens to increase efficiency in mating; a quick method of determining the comparative value of feeds by the use of a nutrient cost factor.

RECOMMENDATIONS

The Department is in need of the following additional equipment and improvements:

An incubation building, $6000, and a judging pavilion, $6000. The original plans for the development of the teaching plant for the Department provided for an incubation building and a large judging pavilion, to be located to the east and to the west, respectively, of the main Poultry Building. These structures as planned are to be one and one-half stories high and similar in design to the Poultry Building on the New York State Fair Grounds at Syracuse. The plan provides that they be connected with the main building by loggias, with a driveway through the loggias leading to the auxiliary buildings. The buildings are very much needed in view of the fact that there is no place for holding poultry shows or for handling large classes in judging. All incubators now have to be operated in the basement of the main building, which is not provided with flues or any method of ventilation and is therefore very unsatisfactory as an incubator cellar.

A service building for the experimenting division, $2000. The experimenting division now occupies an old one-story laying house as a temporary office, and a laying house for feed storage and supplies, and resorts to earth pits for the storage of roots. When the plans were made for the development of the poultry farm, a suitable location was provided for a service building in the space between the windmill and the main avenue running east and west. The construction of a suitable building would meet the immediate need.

One hundred breed-testing houses at the poultry farm, $3000. One hundred or more colony houses will be required for carrying on the breed-testing project if it is to fully meet the probable demand for it, these houses to be located at the north end of the poultry farm.

Commercial laying houses at the poultry farm, $3000. Three large demonstration laying houses should be constructed at the farm in order that the Department may demonstrate to the people of the State the handling of large flocks under the most modern methods of house construction and management. This cannot be accomplished with buildings that are designed especially for teaching feeding practice or the handling of experimental flocks. The new houses should be located in the southwest part of the poultry farm.

Drainage on the poultry farm, $750. The poultry farm requires a large amount of underdrainage. A contour map showing the proposed system of drainage, and estimates of the cost, have been prepared by the Department of Rural Engineering.

Fencing the poultry farm, $1000. A considerable part of the poultry farm, and a part of the teaching plant, are still unfenced. The immediate

needs of the Department are such that much of this fencing should be done at the earliest possible date.

Fruit and ornamental plantings on the poultry farm and teaching plant, $300. The poultry farm now lacks suitable shade in connection with most of the buildings. The Department has been offered, as a gift, ornamental trees for landscape planting at the poultry farm or at the teaching plant to the value of $200. The trees that should be purchased are apple trees, which should supply considerable income and at the same time provide the needed shade.

Extension of the water system at the poultry farm, $600. The extension of the water system at the poultry farm would prove a profitable investment in the saving of labor that would result. The improvements needed are for distribution of the water supply to various parts of the poultry farm.

Construction of roads and walks at the poultry farm, $200. The nature of the soil and the lack of drainage on the poultry farm requires the construction of a large amount of roads and walks, in order that the place may be made accessible and attractive to visitors and convenient of administration.

Repairs to existing buildings at the poultry farm, $500. The old barn at the northwest corner of the farm should be repaired, painted, moved to the north, and placed on new foundations. The barns on the southern part of the farm should be repaired and painted; they are not now in proper keeping with other buildings on college property.

Construction of aviary and yard enclosure at the teaching plant, $300. A suitable area where various types of fowls can be kept under attractive conditions and accessible to the public would be an important addition to the teaching facilities and equipment of the Department. A suitable location for such an aviary would be in the triangle at the junction of the tower road and the marginal road east of the brooder houses.

A special calorimeter for nutrition and embryological research, $2500. The time has come when the construction of a special calorimeter for research in embryology and nutrition would meet an important need. The Department has the graduate students, the buildings, and other equipment which would justify the expenditure necessary for assembling the apparatus for calorimetric work.

JAMES E. RICE,
Professor of Poultry Husbandry.

DEPARTMENT OF RURAL ENGINEERING

TEACHING

The subject of rural engineering as a division in educational work being comparatively new, the staff, the subject matter, and the manner of presentation have all had to be developed together practically from the beginning. The policy of the Department of Rural Engineering has been to offer only a few representative courses and to develop these as much and as rapidly as possible. During the past year, with increased staff and better facilities, considerable progress has been made; better material has been more systematically presented, and the students have been more thoroughly trained.

INVESTIGATION

The most important line of investigation is that in which the Department has been engaged for several years, namely, the design of improved devices for domestic sewage disposal. The perfection of efficient and cheap arrangements adapted to meet all the varied conditions in the State would constitute a great stride toward one of the most important of modern needs, better rural sanitation. A number of years of actual service have proved the efficiency of the devices designed by the Department for houses provided with modern plumbing, so that this phase of the work may be considered as practically completed. A second line of investigation, which has been under way for about a year, has as its object the perfection of a septic tank adapted for use in houses not equipped with complete plumbing. This work, which has all been carried on under the general funds of the Department, is now actively in progress, recent designs being in process of construction. More rapid progress would result if an adequate sum of money were available to make possible the immediate construction and trial of the various designs that have been made.

An investigation of the mathematical properties of the surfaces of various kinds of plow moldboards has been begun by a graduate student in the Department. It is hoped that this investigation will establish the fundamental relations between these surfaces and the physical properties of the types of soil for which the moldboards have been developed.

In cooperation with the Department of Agricultural Chemistry, work has been begun on the relation between drainage and the chemical constituents of muck lands, a line of investigation stimulated by the very considerable amount of extension work done in the reclamation of muck tracts.

EXTENSION

Rural sanitation should be given more attention in extension work than it has received in the past year. Lack of funds and of men has hampered active field work. Several meetings were addressed, however, the reading-course lesson on the subject was extensively distributed, and much individual assistance was given by letter. A number of field trips were made in connection with difficult problems in drainage, or for instructing farm bureau managers in drainage work. One experimental irrigation plant was put in operation. Assistance was given in several demonstrations in the use of dynamite on the farm, and once at a tractor demonstration, in addition to which some aid was given in the planning of barns and other farm buildings. With the amount of special effort made to improve the instructional work, it has been difficult for the instructing staff to find much time for extension activities.

RECOMMENDATIONS

The Department is in need of funds for its investigations in the field of devices for rural sanitation. Funds are needed also for field survey work, so that the staff may keep in direct and constant touch with the engineering needs of the country and also with the ideas and practices of the best farmers in the State. Especially does this apply to the construction of dairy barns and hog houses.

The demands of the Department for extension work have increased from year to year until it has become impossible for the present teaching staff to carry on the work efficiently. In order to meet these increasing demands it will be necessary to have an additional man appointed who can give all or part of his time to the extension service.

H. W. RILEY,
Professor of Rural Engineering.

DEPARTMENT OF AGRICULTURAL CHEMISTRY

TEACHING

The principal work of the Department of Agricultural Chemistry in the past year has been the instruction of students. Ten courses were given, in which 669 students received instruction. In addition a course of lectures for winter-course students was held, with a registration of 275.

EXTENSION

The extension work of the Department has consisted chiefly in the chemical examination of samples of various materials of an agricultural character. During the year 523 samples were analyzed, and the reports of the analyses were sent to residents of the State. There seems to be a growing interest in the use of lime and in the need of lime for soils. Analyses were made of 220 samples of soil and 110 samples of limestone. This has necessitated the appointment of an additional chemist.

GEORGE W. CAVANAUGH,
Professor of Agricultural Chemistry.

DEPARTMENT OF LANDSCAPE ART

TEACHING

With the end of this year Professor Bryant Fleming, former head of the Department of Landscape Art, brought to a close his active connection with the College. Any cooperation that may be given by him in future will be in the nature of advice only.

The Department has further revised its schedule with a view to opening more courses to general election. More attention should be given to the matter of impressing as many students in the College as possible with the opportunities and the methods of making ordinary homes better and more beautiful places in which to live.

The establishment of a fellowship in landscape design in the American Academy at Rome is a matter of particular interest to this Department because the first winner was an assistant here and was for five years a student in the Department. The fellowship is given for three years and pays $1000 a year. It was established by the American Society of Landscape Architects and is open mainly to graduates of recognized landscape schools. In the preliminary competition this Department was represented by nineteen out of a total of twenty-four entries. Of these, thirteen were seniors and six were graduate students. Of the four men selected for the final competition, two were from Cornell, and a third Cornell man was selected for alternate.

EXTENSION

Much of the time of the Department has been taken up by extension work. So many calls have come in from state institutions, village improvement societies, schools, and individuals, that the Department has been forced to limit its attention mostly to institutions and improvement societies, through which the largest number of persons can be reached.

RECOMMENDATIONS

The appointment of a new man on the staff to take charge of the extension work, and possibly, for the present, to do additional teaching in practical landscape construction, would relieve the tension that now exists and would furnish the medium needed to enable the staff to engage in valuable extension activities.

The landscape building should be completed in the few but essential remaining details.

A special lecture fund should be established, which would allow the Department to bring representative men to the College both during the

regular terms and during Farmers' Week. The lectures would be open to the public, and would be of interest to students in many departments.

Opportunity for a larger amount of study should be given to the instructing staff, for the reason that the teaching of landscape work in all its phases is comparatively new. Facilities are needed also for the collection of data and good illustrative material, for both study courses and publications. For example, in the field of plant materials, more accurate data are needed regarding the hardiness of ornamental plants in different sections of the State and under different conditions. Extensive correspondence should be carried on in order to collect these facts. Reliable phenological data are also needed on the comparative blooming time of ornamental trees and shrubs. The whole question as to the intelligent pruning of ornamental plants depends on this point, and yet the published material concerning it is very meager.

Good illustrations taken from New York State farm and village homes are much needed, both for general lectures and for publications. There is plenty of material scattered over the State, but it takes time and money to get the views.

A landscape survey of New York State should be made, with a photographic record of the actual landscape setting, including the farm home, the country roadside, the rural school, the village and town centers, the state institutions, the railroad lines, the barge canal, and all other important features that contribute to the landscape of the State. There are always graduate students in the Department who, if funds were available, could make such a survey.

E. GORTON DAVIS,
R. W. CURTIS,
Assistant Professors of Landscape Art.

DEPARTMENT OF DRAWING

For the past year the registration in the Department of Drawing was as follows: first term, 70; second term, 87; third term, 11; total, 168.

The Department of Drawing does no investigative work as such, yet constant experiments are being made in order to determine the best materials and methods for graphic expression required by scientific students.

While this Department engages directly in no extension work, it prepares most of the illustrations for circulars, bulletins, reading courses, and rural school leaflets. By making the illustrations as artistic as is consistent with accuracy, an indirect æsthetic influence is exercised on the taste of the readers of these publications.

W. C. BAKER,
Professor of Drawing.

DEPARTMENT OF RURAL ECONOMY

The program of instruction given by the Department of Rural Economy has undergone two important changes. The course in conservation has been eliminated, the Department being unable to continue this work with the ever-increasing numbers registered in the more specific courses. A course in marketing and prices has been added, which bids fair to become one of the most important courses given by the Department. While its very newness has attracted a number of students who will be eliminated in the future, the demand for this kind of instruction is growing. The number of students in all courses is increasing

An instructor, H. D. Phillips, has been added to the staff of the Department. Early in April the Department was transferred to more commodious quarters in the Home Economics Building.

A change was made this year in the work offered by the Department in the summer school, primarily for the purpose of giving an outline course to rural school teachers and others interested in rural life. This course, which took up the economic and social status of the rural community, was well attended. The course in marketing and prices was of interest rather to the regular students.

The School for Leadership in Country Life held no session this year.

G. N. LAUMAN,
Professor of Rural Economy.

DEPARTMENT OF RURAL EDUCATION

TEACHING

The most marked development in the Department of Rural Education in the past year has been in the instructional work. Previously the teaching of the Department had been confined to the summer session, but this year four courses were given in the first and second terms to prospective teachers. The total enrollment for the year was 260 students.

INVESTIGATION

All the investigation that has been done has been incidental to the regular activities of the Department. There is need of continued and prolonged study of many of the rural school problems of the State. The present staff is not large enough to meet this need.

EXTENSION

The chief extension activities have centered around the Cornell Rural School Leaflet, which is distributed to all elementary teachers, and to children in the eight grades, in schools under rural supervision in the State of New York. The leaflet is designed to furnish subject matter and inspirational material on nature study, agriculture, home making, and related subjects, for elementary schools, the syllabus issued by the University of the State of New York being used as a basis in its preparation. The September, 1914, number covered the year's work for 1914–15 as outlined by the State Syllabus. The edition was 55,000. By June 1, 1915, 47,988 copies had been distributed. All rural teachers in the State, about 85 per cent of the pupils in training for teaching, and about 75 per cent of the city and village grade teachers, were supplied. Leaflets for boys and girls were issued in November, January, and March. They comprised, respectively, 32, 24, and 48 pages. The edition for each of these three leaflets was 200,000. They have practically all been distributed. Distribution was begun of the new teachers' leaflet for September, 1915, comprising 340 pages and having an edition of 55,000. The records show that during the year 227,360 persons received the leaflets. There were 628,371 copies distributed, in addition to a large number of earlier issues.

School children have been collecting egg clusters of the apple-tree tent caterpillar. During the year reports were received from 1877 schools, showing a total of 4,167,547 egg clusters destroyed. This, however, is only a small part of the work that has really been done. The movement was started two years ago through the influence of the leaflet.

The rural school exhibit held during Farmers' Week was divided into two parts, the corn show and the general exhibit of school work. There were 892 rural schools that sent an ear or two of corn, the ears having been selected by the children in accordance with directions in the leaflet. Prizes for both flint and dent ears were awarded for each county and for the State as a whole. The general exhibit of school work was divided into 14 classes, including work in nature study, drainage, and sewing. Exhibits were sent by 236 schools, and there were 461 separate pieces. First, second, and third prizes were awarded in thirteen groups.

During the year 14,594 letters were received by the editors of the Cornell Rural School Leaflet, and 7407 letters, of which about 3000 were circular letters, were sent out. Also, 8004 letters were received from girls and boys in the rural schools of the State. These were all carefully read, questions were answered, and the letters were recorded. A small gift picture offered to each child from whom three letters were received was sent to 1139 children. The correspondence with children is one of the most important parts of the work, and it is hoped that more letters can be answered personally, thus stimulating greater interest among the boys and girls.

Members of the staff attended, and in most cases addressed, 47 meetings held in the interest of rural education. Visits were made to 46 schools in various parts of the State.

Since January 1, 1915, this Department has given some attention to placing students in teaching positions in high schools. Twenty-five students have thus found positions in this State, and seven outside the State. In addition, the Department has cooperated with other departments in this work.

COOPERATION WITH THE STATE DEPARTMENT OF EDUCATION

This report would not be complete without a statement of the progress that has been made in establishing cooperative relationship with the State Department of Education. An arrangement has been made by which the specialist in agricultural education for the State Department of Education is a lecturer on the staff of the Department of Rural Education at Cornell. Each term this official spends some time at the College, lecturing on rural education and meeting prospective teachers of agriculture and home making. The head of this Department has been made a member of the staff of the State Department of Education.

In the summer of 1915 the specialist in agricultural education called for a conference of the teachers of vocational agriculture, to be held for one week. This Department cooperated with him in conducting this meeting.

Plans have been completed for a series of bulletins to be issued jointly by the Division of Agricultural and Industrial Education of the University of the State of New York and this Department. Bulletin 1 in this series was issued on August 15, 1915.

In cooperation with the Division of Agricultural and Industrial Education, arrangements have been made by which eight seniors will be placed in high schools as assistants to the regular teachers of agriculture. Each senior will stay for a half year.

RECOMMENDATIONS

Provision should be made for meeting the demands on the Department for instruction, otherwise it will be necessary to limit the number of students admitted to the courses offered by the Department. There is also need for instruction for students who do not intend to teach but who, as school patrons, should be in a position to cooperate intelligently with rural educational agencies.

The Department is in need of facilities for cooperating with the Department of Home Economics in preparing teachers of home making.

The increase in the teaching staff should be large enough so that the members may have opportunity for research.

At an early date an experienced person should be put in charge of the junior extension work with persons from twelve to eighteen years of age. There is need for some one to follow this work closely.

GEORGE A. WORKS,
Professor of Rural Education.

DEPARTMENT OF HOME ECONOMICS

TEACHING

The instructional work of the Department of Home Economics includes courses in foods and nutrition, household and institution management, clothing, shelter, and historical courses concerning the family. The number of courses given last year was: first term, 13; second term, 15; winter course, 7; summer school, 7. The total number of students registered in the Department for all courses was 338, as against 322 for the preceding year. The total number of persons giving instruction was two professors, three assistant professors, three instructors, one assistant, and three student assistants. The total clerical force was one financial secretary, part time, one executive secretary, one clerk for reading courses, one stenographer, and part time of a second stenographer. Other persons assisting in the work of the department were: one storekeeper, two housekeepers, one janitor, and, for the cafeteria, one baker, one assistant baker, one cook, one assistant cook, two cleaners, and a varying number of students paid by the hour.

CAFETERIA

The annual receipts of the Home Economics Cafeteria amount to about $44,000. Deducting the expenditures necessary for carrying on this work, a net profit of about $4000 is shown.

EXTENSION

The extension work of the Department consists mainly in the publication of reading-course lessons for the farm home, and in the organization of Cornell study clubs, the preparation of programs for clubs, correspondence with farm women, work at farm home demonstration schools, and junior extension work in home economics in cooperation with the Department of Rural Education.

The reading-course lessons were sent to 42,929 readers, 5197 of whom were added in the past year. Twelve lessons were published, one for each month. The Cornell study clubs numbered 122, including 29 new clubs organized in 1914–15. Members of the Department visited 56 of these clubs this year. Letters written in connection with these clubs amounted to 2682. There were 274 lectures given exclusive of those at farm home demonstration schools, which are reported farther on.

The Department has conducted this year 38 farm home demonstration schools, in 25 counties. Of these schools 23 were held in connection

with farm demonstration schools, and 15 were held independently. There were 35 schools lasting through five days, 1 school for two days, 1 for three days, and 1 consisting of four evening sessions for business women. At 36 of the schools there was one session a day; at 2 schools, two sessions a day were given. The total number of persons enrolled in the 38 schools was 1238, making an average enrollment per school of 32.6. The average number of instructors per school was 1.1. The single paid admissions during the season numbered 583. The average attendance per session was 32.9. The average percentage of attendance among enrolled members, recorded for 16 schools, was 88.3. The largest enrollment was 60, at Whitney Point, in Broome County; the smallest enrollment was 14, at Horseheads. Schools were held during 25 weeks (exclusive of Farmers' Week), giving an average of 1.5 schools a week. Not more than 3 schools were held in any one week. One member of the staff has given her entire time to farm demonstration work under the Smith-Lever fund.

The entire cost to the State for instruction in the farm home demonstration schools, exclusive of salaries of staff members, was $206.59. This figure is the difference between the total expenses, $1173.82 (for supplies, transportation of equipment, traveling expenses, and salaries to outside lecturers), and the total fees received, $967.23 (for enrolled members and for single admissions). The average cost per school to the State was $5.44; the average cost per enrolled member was 16.7 cents for the school week, or approximately 5.6 cents per session.

Instruction in the schools this year has been mainly in food values, elementary dietetics, and the methods and principles of cooking.

Junior extension in home economics is carried on in cooperation with the Department of Rural Education, and under the joint supervision of the College of Agriculture and the State Education Department. This work is developed by projects rather than by clubs. Instruction is given chiefly to groups of rural school teachers, at conferences called by the superintendents of the schools. This year instruction has also been given directly to the children in rural schools, for the purpose of developing the projects. Ultimately instruction will be given to teachers only. The projects culminate in school fairs, at which the results are exhibited and judged by the specialist in junior home economics from the College. A project is being carried on in rural high schools that have no courses in home making. The purpose of this project is threefold: (1) to give instruction in home making to girls who have no opportunity of getting such instruction through the school system; (2) to demonstrate to the community the scope of a high school course in home making; (3) to create a desire on the part of the community for a permanent course in home making. In connection with the junior extension work 931 letters

were written this year, and there were 10 demonstrations and 11 lectures not in connection with the school system. There were 83 demonstrations and talks given in schools, and judging was done at 10 school fairs.

FLORA ROSE,
MARTHA VAN RENSSELAER,
Professors of Home Economics.

DEPARTMENT OF METEOROLOGY

During the past year plans have been formulated for strengthening the course given by the Department of Meteorology, and the preliminary steps have been taken toward their execution. These plans provide for a weekly laboratory period in addition to the regular lectures, and also for giving the course in two terms instead of in only one. A temporary laboratory has been provided in Rockefeller Hall, but a permanent one is needed. That there is a healthy interest in the work of the Department is shown by the number of registrations, which amounted to 242.

WILFORD M. WILSON,
Professor of Meteorology.

FARM BUREAU OFFICE

On September 30, 1915, there were 31 farm bureaus in New York State having managers at work. In two other counties, Albany and Tioga, the organization of a farm bureau association had been completed. These 33 bureaus serve 67.8 per cent of all the farms in the State, and the counties comprise 67.6 per cent of all the area of the State in farms. In other words, of the total area of 22,030,367 acres in the State in farms, 14,904,980 acres are in counties having a farm bureau organization; and of the 215,797 farms in the State, 146,203 are served by farm bureau organizations. The total membership in the bureau associations on July 1 was 8769.

The total estimated resources in farm bureau work in 1915 were $107,271.25, or $3973 per county. The estimated expenditures for the same period were $98,661, or $3654.11 per county. The chief contributors to the support of the work were: Boards of Supervisors, $40,248.29; New York State Department of Agriculture, $16,200; United States Department of Agriculture, $17,400; memberships, $8276.50; Chambers of Commerce, $6361; railroads (cash), $6298; private and corporation contributions, $4535; miscellaneous, including balances from previous year, $8553.46.

The principal items of expense of the bureau in 1915 were: salaries, $53,810; traveling expenses, $4925; office rent (including values not cash), $5963; stenographic help, $8825; office equipment, printing, telegraph, and telephone, $6778; automobiles — purchase cost, repairs, and maintenance, $10,915; new equipment, $1915; expert help, $1378; miscellaneous, $4152.

The total amount of field test and demonstration work laid out up to July 1, 1915, was 3128 cooperative tests, distributed as follows: orchard renovation 344, meadow fertilization 212, corn silage 269, alfalfa 329, vetch 369, other legumes 150, potato work 388, use of lime 409, oat smut control 224, miscellaneous 434. This is an average of 105 tests per county. Up to July 1, 1064 farm management surveys had been taken and 340 livestock demonstrations held, and the total attendance at 608 field meetings held previous to July 1 was 14,679.

Eighty-six subsidiary or supplementary organizations had been formed or assisted in organizing by the farm bureaus, as follows: cow testing associations, 38; breeders' associations, 14; poultry associations, 4; cooperative buying and selling associations, 17; potato associations (chiefly for standardization), 7; miscellaneous, 6.

The efficiency of farm bureau work may perhaps be best indicated by the total number of persons who are brought into effective contact with

the bureau organization and leader, and led to do something for themselves and their neighborhoods. Probably the best means of accomplishing this are: (1) by cooperation in the field tests; (2) by demonstration meetings on the test plots in the field; (3) by membership in live organizations; and (4) by personal contact through farm visits and office calls.

The five counties in the State having the largest membership in their farm bureau associations are: Otsego, with 866; Wyoming, with 620; Chenango, with 580; Monroe, with 480; and Orange, with 415. The farm bureaus in these five counties are probably among the seven or eight strongest in the State.

Of the 31 associations, about half are in good condition; there is still room for growth and improvement in most of these, but they are in good working order and have no very difficult problems. In the other associations, the plan is satisfactory but it is not being properly carried out; in these counties it will be necessary to in some way arouse more enthusiasm and get the plan into better working condition.

The activities of the central office may be divided into three principal groups — organization work, assisting in the making of programs and projects, and office work.

The organization work consists in helping to perfect the organization and methods of work in old counties, and in the organization of bureaus in new counties. Since January 1, 1915, bureaus have been organized in five counties and have begun work: Orange, on January 1; Chenango, on February 15; Saratoga, on February 15; Sullivan, on May 1; and Westchester, on August 1. The organization of bureaus in Tioga and Albany Counties has been completed and these bureaus are ready to begin work.

During the winter the main field work of the central office was given to the drawing of programs and projects in the counties. Twenty-eight of the thirty-one counties now have fairly definite programs. At least four of these programs are comprehensive, fit the needs of the counties, and are practically all that could be desired; fourteen counties have programs that may be considered good; ten are only fair in their comprehensiveness and completeness. Projects have been drawn in practically all the counties to carry out the programs.

The director and the assistant director have spent practically as many days in the field as in the office. One hundred days have been spent in the counties having farm bureaus (an average of nearly four days per county), meeting committees, inspecting the work, helping to draw programs and projects, and organizing the bureaus. Organization has taken more time than any other type of work. An average of four individual conferences have been held with each manager on some feature of the work.

The principal agricultural problems in the farm bureau counties may be divided into four groups: (1) in relation to soils, (2) in relation to crops, (3) in relation to livestock, and (4) in relation to the people and the farmstead.

In relation to soils the principal problems seem to be: the use of lime to correct acidity, mentioned by 27 managers; drainage, mentioned by 21 managers; increased fertility and the use of commercial fertilizers, mentioned by 19 managers; the correction of the physical condition of a soil by the addition of humus, mentioned by 16 managers. In addition to these, tillage, including deeper plowing, was mentioned as an important soil problem by 11 managers, the necessity of the use of acid phosphate in restoring soil fertility by 8 managers, and the need of a definite rotation by 4 managers.

In relation to crops the principal problems seem to be: the introduction of legumes and protein crops for the dairy; the increasing of cash crop diversity; the control of insect pests and diseases; the determination of the best varieties, particularly of seed corn; the standardization of crops; the improvement of pastures; orchard renovation; seed selection; improvement of quality; the adaptation of crop and variety to soil; and marketing. The use of legumes was mentioned by 25 managers, cash crops and diversity by 21, control of insects and diseases by 10, rotation by 7, standardization of markets by 6, and tillage by 5.

In relation to livestock the principal problems seem to be: elimination of poor cows by any possible means, but chiefly through cow testing association work; the improvement of stock, chiefly through purebreds; and the reduction of the cost of feeds, chiefly by the use of silage and better roughage. A few managers mentioned the keeping of records and the price of the product, while 7 mentioned marketing and 6 mentioned diversity by the introduction of hogs, horses, poultry, and young stock. The need of better or purebred stock was mentioned by 22 managers, the elimination of poor cows by 18, and reduction in the cost of feed by 11.

In relation to the problems of the people and of the farmstead in the various counties, there was great difference of opinion. The use of better business methods, including cheaper supplies and standardization, was mentioned as important by 18 men; home improvement, including higher ideals, was mentioned by 17 men; school problems were mentioned by 14 men. Other problems mentioned were the need of more public spirit, increased social and reading facilities, lack of cooperation, and local leadership.

M. C. BURRITT,
Director of Farm Bureaus.

DEPARTMENT OF EXTENSION TEACHING

TEACHING

Four courses were given by the Department of Extension Teaching this year, including one winter course. The enrollment was 272, as compared with 244 for the preceding year.

The various competitions in public speaking were well contested and interest in them was marked. The speakers in these contests were coached by members of the departmental staff.

EXTENSION

The extension activities arranged by the Department in the past year covered the following lines: Farmers' Week, farm demonstration schools, field demonstrations, farm demonstration cars, demonstrations by way of educational exhibit material at the State Fair and at town and county fairs, reading-course clubs, lecture courses, and demonstrations and individual lectures by members of the college staff at community meetings and agricultural assembles. Attendance at these various meetings and demonstrations was as follows: Farmers' Week, 4100; farm demonstration schools, 1741; farm demonstration cars, 6484; individual meetings and demonstrations, 62,672; total, 74,997. Letters received by the Department amounted to 21,612, and there were 22,292 letters sent out.

FARMERS' WEEK

The eighth annual Farmers' Week was held during the week of February 8 to 13. The registered attendance was 3077, an increase of 526, or more than 20 per cent, over the registration for 1914. It was impossible to register all the visitors, but the total attendance during the week was estimated at about 4100. Of the persons registered, about 96 per cent were from New York State, representing 58 counties. Twenty-one States and the District of Columbia were represented, and delegates were present from Hawaii and Japan. In spite of the unusually large crowds there was less congestion than usual, as there were three new buildings to help relieve conditions — Caldwell Hall, the new Animal Husbandry Building, and the Stock Judging Pavilion.

The program for the week presented fewer lectures than in former years, the influence of the idea of education by demonstration being shown in the increased number of laboratory courses, competitions, exhibitions, and demonstrations that were introduced. Consequently there were fewer lecturers than usual from outside the College, more of the work being conducted by members of the staff. The faculty was left

free to do this by the help of the students, who worked on various committees and took charge of much of the great amount of detail incident to an enterprise as comprehensive as Farmers' Week. The work of these student committees has become so important that it would be almost impossible to conduct Farmers' Week without their assistance.

An added feature of the week was the free exhibition of motion pictures in Bailey Hall during the noon hour each day.

There were held during the week 269 lectures, 26 demonstrations, 17 contests, 38 laboratory courses, and 15 entertainments and banquets. The lecturers from outside the College numbered 65. There were 16 conventions and conferences held by various organizations.

FARM DEMONSTRATION SCHOOLS

There were held in the past year 47 farm demonstration schools, in 26 counties. The total enrollment was 1741, the average enrollment per school was 37, the average attendance per session was 25.4, and the average number of instructors per school was 2.9. The largest enrollment was 63, at Newfane, in Niagara County; this school also had the best percentage of attendance, this being 86. The lowest attendance was at Union Springs, where the total enrollment was 20 and the average attendance per session was 9; the school at Union Springs was also the weakest school held in the preceding season. The first school was held during the week of November 30 to December 4, the last during the week of March 22 to 26. Not more than four schools were held in any one week, and only one school was held in the last week of the season. The average number of schools per week was 3.2.

It is not apparent that the demonstration school season should be shortened. The weather has frequently been a factor for low attendance during January and February. This year, out of five schools having an enrollment below 30, one was held in December, one in the third week of April, and three in January and February. With more attention given from the College to local organization and a study of local needs, the average attendance might be very materially increased; and in normal years schools should be successful in this particular throughout the period from December 1 to March 31.

In certain sections, notably Ontario, Niagara, and Monroe Counties, fruit schools, offering instruction in orchard management, entomology, and plant pathology, might be advantageously arranged to cover a circuit in the fruit belt. This suggestion is offered as an experiment to meet special needs.

The greatest demand for schools is in animal husbandry, followed in order by farm crops, soils, fruit growing, poultry, farm management,

plant pathology, insect pests, vegetable gardening, farm plumbing, gas engines, agricultural chemistry. There is need for additional workers in animal husbandry, farm crops, and soils in the order named, several applications for schools having been withdrawn because of inability of the Department to furnish instruction in these subjects.

A comparison of figures for the last several years shows that many counties have not been reached through schools and that in some counties two or three schools have been held each season. While the advanced nature of the work will not permit an immediate equitable distribution of schools geographically, it is planned to work toward this end.

The season has been a successful one. Attendance was reported excellent in nearly seventy-five per cent of the schools. Replies to a circular letter concerning the usefulness of the schools, received to date, are summarized as follows: favorable comments, 510; unfavorable comments, 14; neutral statements, 37.

DEMONSTRATION CARS

Demonstration cars were run as follows:

One in animal husbandry, dairy industry, and farm management, in cooperation with the New York Central Railroad, from March 23 to April 10. Stops were made at 17 places and the total attendance was 2575.

One in animal husbandry, farm crops, and soil technology, in cooperation with the Erie Railroad, from April 13 to April 20. Stops were made at 14 places and the total attendance was 529.

One in pomology, in cooperation with the New York State Department of Agriculture and the New York Central Railroad, from August 2 to August 21. Stops were made at 38 places and the total attendance was 2751.

One in farm crops, plant breeding, and plant pathology, in cooperation with the New York Central Railroad, from August 25 to September 4. Stops were made at 12 places and the total attendance was 629.

FAIR EXHIBITS

This year, in arranging for exhibits to be sent to town and county fairs, the local associations were asked to pay all transportation charges and all traveling expenses. Exhibits were sent to 18 fairs. At 7 fairs members of the college staff acted as judges of farm produce and livestock. Eight fair associations withdrew their requests for exhibits, on advice that they would have to pay all expenses.

The following departments were represented with exhibits at the New York State Fair at Syracuse, New York, September 13 to 18: Animal

Husbandry, Forestry, Plant Breeding, Dairy Industry, Farm Crops, Botany (Plant Physiology), Pomology, Entomology (including Ornithology), Vegetable Gardening, Soil Technology, Farm Management, Poultry Husbandry, Agricultural Chemistry, Rural Engineering, Extension Teaching, Plant Pathology, Floriculture.

CORNELL READING COURSE FOR THE FARM

The number of persons enrolled for the Cornell Reading Course for the Farm has increased during the year by over 120 per cent. The enrollment has increased rapidly during the last three years, as is shown by the following figures:

Year	Enrollment
1912–13	3,884
1913–14	5,877
1914–15	12,984

In the past year 18 new Cornell study clubs have been organized, and 7 clubs organized in earlier years have reported. Fourteen meetings have been attended in the interest of study club work.

Instruction in accordance with modern correspondence methods is now offered in the advanced reading courses in fruit growing and vegetable gardening. Textbooks, bulletins, questions, and correspondence are used. The required work is graded and returned with comments through the cooperation of the Departments of Pomology and Vegetable Gardening. An effort is made to adapt the principles and practices discussed to local conditions. The textbooks are bought from the publishers by members of the course. No college credit nor certificate is granted.

RECOMMENDATIONS

Previous reports of this Department have emphasized the necessity of establishing demonstration schools, lecture and correspondence courses, exhibits, instruction for undergraduates, and other forms of extension activity. These lines have been established. It is now a question of their normal and consistent growth.

No longer is it practicable to set forth standardized advice in the growing of crops and animals to be applicable throughout the State. Conditions are too varied. Modifications are so numerous as to almost overthrow a principle, and regional application must be made. In order to do this, the experiment station must first make the experiments, and the extension staff must then study the results sufficiently to make effective applications. The grape district of Chautauqua and the truck districts of Monroe County and Long Island are examples of localities

needing special principles. So great is this need on Long Island that the appointment of a properly trained man to give full time to that section is recommended.

The recognition of regional crop lines in the State brings attention to the need of an artificial division of the State, so that one man may give his attention to the general needs of a comparatively small area. Ultimately from twelve to fifteen such divisions should be made, but in the near future there should be at least four.

Now that farm bureaus are established and the extension service is growing through aid from the Federal Government, there is need of the closest correlation of all State agricultural agencies, with particular attention to the extension service and the farm bureaus. This is rapidly being brought about.

In the general division of funds of the College in the extension service, the time has come when there is need, not of additional new lines, but that the old should be strengthened with additional appropriations. The fundamental subjects of farm crops, soils, and animal husbandry must have many times their present assistance if they are to meet the demands in this field.

A new subject arising from the demands of the people is the teaching of community music, or the aiding in community grouping through desire of the people to express themselves collectively by means of song. This is psychologically at the bottom of successful cooperation. More attention is to be given to this subject through the presence on the regular departmental staff of a man who is qualified for this work.

By reason of the increase in the extension staff, the headquarters of the Department are crowded. There are three extension men in need of office space.

In order to continue a consistent growth of that which is now established, and to meet the demand for the development of rural interests in the State, an increase in funds for extension service is imperative. The time has come when the extension funds should bear a higher ratio to the general maintenance funds.

C. H. TUCK,
Professor of Extension Teaching.

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PHYSIOLOGICAL STUDIES OF BACILLUS RADICICOLA OF CANADA FIELD PEA

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PHYSIOLOGICAL STUDIES OF BACILLUS RADICICOLA OF CANADA FIELD PEA[1]

MARTIN J. PRUCHA

INTRODUCTION

Ever since the discovery that the formation of nodules on the roots of legumes is associated with a definite microorganism, there have appeared on the market pure cultures of this organism for the artificial inoculation of leguminous plants. Nobbe and Hiltner (1897)[2] first caused to be placed on the market a pure culture called nitragin,[3] in which the medium employed was gelatin. The efficiency of the culture was low, and Nobbe and Hiltner explained this by ascribing to the culture a loss of infecting power due to the medium used. Moore (1905) stated, as a result of his work, that the virulence of the organism was impaired when it was propagated on nitrogenous media, and consequently he used a nitrogen-free medium.

The same opinion has been held by various other investigators, and is observed by all firms and institutions that distribute pure cultures of the legume organism. Despite the fact that media low in nitrogen have been employed, the results with pure cultures have not always been satisfactory, and Kellerman (1912) has stated that the pure cultures have not been as efficient as field soil. It would seem, then, that the conditions of isolation and cultivation of the legume organism must influence the organism, or that possibly the soil conditions would exert some influence on the efficiency of the organism to effect inoculation or would have an influence on the plant to resist infection.

SCOPE OF THE INVESTIGATION

With these ideas in mind, the investigation herewith reported was undertaken. It is concerned with the following: (1) Isolation and identification of the organism causing nodule development on the roots of Canada field pea; (2) A study of the influence of various factors on nodule

[1] Laboratory of Plant Physiology, Contribution No. 15.
[2] Dates in parenthesis refer to bibliography, page 79.
[3] This is not the nitragin now on the market.

development in Canada field pea when the plant is grown in water or soil cultures; (3) A study of the influence of various environmental conditions on the infecting power of the organism.

METHOD OF INVESTIGATION

Organism

Bacillus radicicola from Canada field pea was used for all the experiments except number 11, for which the organism from alfalfa was used. The organism was isolated as described on page 14. The stock culture was kept in the laboratory on agar slopes of medium 335, and was exposed to diffused light during the entire investigation. It was transferred at irregular intervals of time varying from one to three months.

Media

The various kinds of media used are referred to in the text by their laboratory numbers. In table 1 are given the laboratory numbers and the composition of the principal media employed. In addition to these a number of other media were used, and these are described subsequently. All the media were prepared according to the recommendations on the Descriptive Chart of the Society of American Bacteriologists.

Sterilization of utensils

Strict precautions were observed in sterilizing all the utensils. Glassware was sterilized for two hours at from 150° to 170° C. Scalpels and similar instruments, which resist high temperature, were heated in the flame. For work requiring air free from dust, a room was used into which a stream of steam was allowed to flow until the air was saturated; after condensation of the steam, the air in the room was conspicuously free from any dust.

Sterilization of seed

The experiments in Part III required seed free from *B. radicicola*. It was necessary, therefore, to sterilize the seed. In experiments 10 and 11, 95-per-cent alcohol was used, the seed being treated for thirty seconds. In experiments 12 and 13 a solution of bleaching powder was used. The author is indebted for this method to Professor J. K. Wilson, of Cornell University. The solution is prepared by mixing 8 grams of bleaching

TABLE 1. LABORATORY NUMBERS, COMPOSITION, AND REACTION OF MEDIA

Laboratory number	Composition	Reaction
Medium 101	0.2 gram $MgSO_4$ 1 gram KH_2PO_4 0.3 gram $Ca(NO_3)_2$ 0.01 gram $FeCl_3$ 1000 cc. distilled water	Not changed
Medium 300	15 grams agar 3 grams Liebig's beef extract 10 grams Witte's peptone 1000 cc. distilled water	+1, Fuller's scale
Medium 310	Same as 300, plus 2 per cent dextrose	Neutral
Medium 331	15 grams agar 10 grams cane sugar 1 gram KH_2PO_4 0.2 gram $MgSO_4$	Not changed
Medium 334	15 grams agar 0.2 gram K_2HPO_4 0.2 gram $MgSO_4$ 0.2 gram NaCl 0.2 gram $CaSO_4$ 0.2 gram $CaCO_3$ 1000 cc. tap water	Not changed
Medium 335	Same as 334, plus 20 grams cane sugar	Not changed
Medium 337	Same as 335, plus 10 grams Witte's peptone	Not changed
Medium 400	15 grams agar 3 grams Liebig's beef extract 20 grams Witte's peptone 1000 cc. distilled water	+1, Fuller's scale
Crone's solution	1 gram KNO_3 0.5 gram $Fe_3(PO_4)_2$ 0.25 gram $CaSO_4$ (gypsum) 2000 cc. distilled water	Not changed
Pfeffer's solution	4 grams $Ca(NO_3)_2$ 1 gram KNO_3 1 gram $MgSO_4$ 0.5 gram KCl 0.06 gram $FeCl_3$ 6000 cc. distilled water	Not changed

powder with 140 cubic centimeters of water; after standing for a few hours, the clear liquid is decanted and is then ready for use. Seed was kept for three hours in this solution. According to Professor Wilson's results, seed treated in this way is completely sterilized. This method of seed sterilization will later be published in detail.

That the methods of seed sterilization employed were effective was proved by a large number of experiments, and particularly by experiments with soy beans. The organism producing nodules in soy bean is not present in the soil of this region, and in all the experiments made not a single nodule developed in the cultures in which sterilized seed was used unless the plants were subsequently inoculated. Unsterilized seed occasionally produced plants with nodules.

Sterilization of media and soil

All the media used for pure cultures, if in test tubes of small volume, were sterilized in an autoclave for fifteen minutes at 120° C.

In experiments 10, 11, 12, and 13 it was necessary to sterilize the soil in which the plants were grown. Three-inch flowerpots and glass tumblers, each containing about 300 grams of soil, were used for this purpose. These were sterilized for three hours at 120° C., in a large canner's retort. This retort was found very useful, since several hundred of the flowerpots could be sterilized at one time.

Method of growing the plants

In experiments 1, 2, 3, 4, 5, and 6, the plants were grown in water cultures; in experiments 7, 8, 9, 10, 11, 12, and 13 they were grown in soil.

For the water cultures glass vessels were employed. The vessels were filled with the nutrient solution and the opening was covered with paraffin paper. The seed was then germinated in a moist chamber, and when the radicle was about three centimeters long it was inserted into the solution through a small hole in the paraffin paper, allowing the cotyledons to rest on top of the paper.

For the soil cultures flowerpots and glass tumblers were used. These were filled with sandy soil, were covered with paper, and, for experiments 10, 11, 12, and 13, were sterilized. The seed was planted directly in the soil, the paper covers being kept on until the seedlings began to push them off.

Distilled water was used for watering the plants in experiments 1, 2, 3, 4, 5, 6, 7, 8, and 9. In experiments 10, 11, 12, and 13, boiled tap water was used.

The plants in all the experiments were grown in the greenhouse. When special precautions were necessary to guard against contamination during the growing period, the plants were kept in an especially constructed culture room. For this purpose a part of the greenhouse was set off by a partition. Cracks in the walls and around the panes of glass were filled with plaster of paris. For ventilation, two panes of glass were replaced by a special frame fitted with a layer of cotton held between two pieces of cheesecloth.

Inoculations

Inoculations were made at the time of planting the seeds or within a day or two following. The culture of the organism to be used for inoculation was introduced into sterile water, and the infusion was then added to the soil or the water culture in which the plants were grown. In some experiments quantitative inoculation was made, in which a specific amount of the infusion was added.

Examination of plants for nodules

Nodules usually appeared in about two weeks. The plants were examined at the end of three weeks. The roots were washed and the nodules were counted, and a note was made of the size and the place of attachment of the nodules. Since the soil in the vicinity of Ithaca is well inoculated with the Canada field pea organism, plants kept longer than three weeks were subject to some contamination.

Special method for growing plants under sterile conditions

For certain experiments it was necessary to maintain absolutely sterile conditions throughout the period of experiment. The method employed was as follows: A large glass cylinder, 65 centimeters high and 10 centimeters in diameter, was used as a growth chamber. In the bottom of the cylinder a few pieces of broken flowerpot were placed and were just covered with water, and on the top of these was set a four-inch pot, filled with a sandy soil. The cylinder was plugged with cotton, through which was passed a glass tube 7 millimeters in diameter and 65 centimeters long, the lower end resting on the surface of the soil in the pot

and the upper end protruding above the cotton plug. The tube was plugged at its upper end with cotton. The whole was sterilized in the autoclave for five hours at 15 pounds pressure.

The seeds were sterilized by the bleaching-powder method. The sterilized seed were dropped into the pots through the glass tube, and by manipulation of the tube they were buried in the soil. The soil of the pots was inoculated by introducing through the tube a few cubic centimeters of water containing the nodule-forming organisms.

PART I. ISOLATION AND IDENTIFICATION OF THE ORGANISM

ISOLATION OF BACILLUS RADICICOLA

On October 10, 1910, a field pea plant 30 centimeters high, with a great abundance of nodules, was procured. The whole plant was washed thoroughly in running water. One of the nodules, of firm consistency, was selected and cut off in such a way as to leave about 3 centimeters of the root on each side of the nodule; cut off in this way the nodule is more easily manipulated. The nodule was then disinfected in a solution of one part of formalin to forty parts of water, for five minutes. Four petri dishes were prepared, each containing a few drops of sterile water. The nodule, after being disinfected, was washed in sterile water, placed on a filter paper, and cut open, and with a pointed scalpel a part of the central tissue was removed and placed in petri dish 1. This nodule tissue was crushed and mixed with the water. Three loopfuls of this infusion was transferred from plate 1 to plate 2, three loopfuls from plate 2 to plate 3, and three loopfuls from plate 3 to plate 4. Ten cubic centimeters of medium 331 were then poured into each petri dish, and after sufficient agitation to effect equal distribution of the organisms the plates were allowed to incubate at 20° C. In three days a few colonies characteristic of the nodule organism became visible on plate 1; on the other plates plenty of colonies were present, but were visible only by the microscope. In ten days the small colonies became large enough to be conveniently transferred.

As far as could be ascertained from the general appearance of the colonies, all the plates contained only one organism. The large colonies that developed on plate 1 appeared to be giant colonies, having started from small pieces of the nodule tissue in which a large number of the organisms were held. In order to obtain a pure culture of this organism, one of the

small colonies was introduced into 5 cubic centimeters of sterile water in a test tube, and from this infusion a number of petri dishes of different dilutions were again prepared. From one of the colonies that developed on these petri dishes a transfer was made on agar slope with medium 335. This culture was used in all the experiments except experiment 11. The stock culture was kept on a shelf in the laboratory, and consequently was exposed for nearly three years to diffused light and to the ordinary variations of temperature and other atmospheric changes. The transferring of the stock culture was made at irregular intervals of time varying from one to three months, and the cultures were kept in test tubes on agar slopes of medium 335.

IDENTIFICATION OF THE ORGANISM

In order to be certain that the organism isolated was the causal organism of the nodules on Canada field peas, the following procedure was followed: (1) Canada field peas were grown under sterile conditions and were inoculated with this organism; (2) from one of the nodules that developed under sterile conditions a culture, No. 2, was isolated by the same method as described above; (3) the original culture and the culture No. 2 were again tested as to their ability to cause the development of nodules on Canada field peas under sterile conditions; (4) the two cultures were compared in the laboratory with respect to their morphological characters and physiological activities.

Ten Canada field peas were grown under sterile conditions according to the method described on page 13, one plant in each of ten glass cylinders. Five of the plants were inoculated with the above organism, and five were left without inoculation, as controls. At the end of six weeks the plants were examined. They had made a fair growth, having reached a height of 60 centimeters. They were spindling, however, the leaves were small, and the root system was very poorly developed. All the inoculated plants had nodules on their roots, while the controls were free from any nodules. Each plant and the soil in which it was grown were examined for contamination. One of the controls was found to be contaminated with a mold, and one of the inoculated plants was contaminated with a yellow organism. Four of the controls were sterile, and four of the inoculated plants were found to be sterile with respect to organisms other than *B. radicicola*.

A pure culture of the organism was isolated from a nodule found on one of the plants grown under sterile conditions. This organism was again tested as to its ability to produce nodules on Canada field peas. Fifteen Canada field pea plants were grown under sterile conditions again, in a similar manner to that described above. Five were inoculated with this organism, five were inoculated with the original organism, and five were left as controls. Again all the plants inoculated with both the cultures developed nodules on their roots, while the controls had none. The organism that was isolated on October 10, 1910, therefore, was the causal organism of nodules on Canada field pea plants, and as far as could be determined by laboratory methods it was also a pure culture.

The two cultures of the organism — the one isolated originally, and the other isolated from a nodule of a plant grown under sterile conditions — were studied in the laboratory with respect to their morphology and their physiological activities. An exhaustive study of this phase was not undertaken, the study being carried only far enough to show whether the two cultures were the same organism. The study consisted in propagating the two cultures on various media and in comparing and describing their cultural and biochemical features. The descriptions were recorded on the Descriptive Chart adopted for such use by the Society of American Bacteriologists (1907).

Morphology of the organism

Bacillus radicicola of Canada field pea produces no spores when propagated on the artificial media in the laboratory. In a young culture on artificial media, the organism is in the form of small rods about one micron long. In this form it is able to multiply by fission, like other bacteria. Under certain conditions — for example, with the addition of certain nutrients, such as sugar, to the media — some of these small rods develop into large cells, which are generally called bacteroids. Some of the bacteroids assume the characteristic X and Y forms, the same as are found in the nodules. The development of the bacteroids seems to be largely a matter of nutrition, and the bacteroids are not a degenerate form, but a normal form, of the organism.

In a culture twenty-four hours old on an agar slope the organism is very motile. As the agar-slope culture gets older, fewer and fewer of the organisms show motility, until in a culture about two weeks old no motility

is detected. Motility seems to be influenced by environmental conditions. This point has not been studied extensively, beyond the observation that on nitrogenous media the motility is lost sooner than on nitrogen-free media.

Since the generic name of the organism depends on the presence and the place of attachment of flagella, and since there has been so much uncertainty on this point, an effort was made to demonstrate the number and the arrangement of the flagella. Beyerinck (1890) was the first who claimed to have isolated the organism in a pure culture. He described it as having one polar flagellum, and named it *Bacillus radicicola*. In 1905, Moore, agreeing with Beycrinck as to the number of flagella and wishing to conform to Migula's classification, changed the generic name from *Bacillus* to *Pseudomonas*. Edwards and Barlow (1909) found only one long, whiplike flagellum, thus agreeing with Beyerinck and Moore. De' Rossi (1907) was the first investigator who found the organism of *Vicia faba* to have about eight flagella with a peritrichic arrangement. Zipfel (1912) agreed with de' Rossi, stating that the organism has numerous flagella. In 1912 Kellerman, using a special method, also succeeded in staining the organism of several leguminous plants. He likewise found the organism to have several flagella peritrichically arranged.

In this investigation the following method was used for staining the organism of Canada field pea for flagella:

An agar slope culture twenty hours old, on medium 335 at 24° C., was very carefully transferred into 3 cubic centimeters of sterile distilled water in a test tube. This was allowed to stand for about four hours at a constant temperature, without being shaken or disturbed in any way. A drop of this infusion was placed on a cover glass and allowed to dry at room temperature, and when dry it was stained.

It was essential that the cover glasses should be clean. To this end they were treated with a cleaning solution of potassium bichromate and sulfuric acid, washed in water, placed in alcohol, and finally dried with a piece of cheesecloth which had been treated with ether in order to get rid of any fats. The cover glasses were then placed in a petri dish and baked in the oven for three hours at 200° C. If cover glasses are treated in this way a large amount of difficulty in the staining of flagella is avoided.

Pitfield's mordant as modified by Muir, and carbol fuchsin, were used for staining. The mordant has the following composition:

	Cubic centimeters
Tannic acid, 10 per cent aqueous solution	10
Corrosive sublimate, saturated aqueous solution	5
Alum, saturated aqueous solution	5
Carbol fuchsin	5

The mordant was applied for six minutes and the preparation was then very thoroughly washed with water. Carbol fuchsin was then applied for nine minutes.

It was found that the organism from Canada field pea has peritrichic arrangement of flagella. The largest number of flagella observed was six, arising from any part of the organism, and the indications were that the organism may have an even larger number. According to Migula's classification the organism is *Bacillus*.

Cultural and biochemical features

The surface colonies in a petri dish on agar medium 335 are colorless, watery, and very viscous. When ten days old, at 20° C., they are about 3 millimeters in diameter, although occasionally colonies 10 millimeters in diameter may develop. The colonies under the surface are invariably of spindle shape. Under the 16-millimeter objective the microscopic structure appears granular.

On agar slope with peptone and beef extract, the growth is watery, scanty, and colorless at first; after long standing it becomes brownish. In standard gelatin stab the growth becomes brownish. On agar slope with medium 335 to which 0.5 per cent of potassium or calcium nitrate had been added, the growth becomes opaque and iridescent. In all the standard media free from sugar the growth is scanty. In the presence of dextrose, saccharose, maltose, or glycerin, much more abundant growth takes place. Lactose and galactose increase the growth only slightly, while the addition of levulose tends to inhibit it. Two per cent of levulose added to media entirely inhibits the growth. Whether this is due to this sugar or to some impurity in it was not determined.

The organism does not produce any indol, hydrogen sulfite, or ammonia. It does not reduce nitrates and does not liquefy a 12-per-cent gelatin stab at 20° C., but when grown in milk it partly digests the casein without curdling the milk. It does not produce any gas from the sugars in fer-

mentation tubes. From dextrose, maltose, and saccharose it produces a slight amount of some acid. Neutral litmus milk becomes alkaline after the organism has grown in it for about two weeks.

The organism of Canada field pea does not have any strikingly characteristic colony features by which it can be distinguished from other microorganisms. The group number of the organism, according to the chart of the Society of American Bacteriologists, was found to be B. 222.2322033.

PART II. INFLUENCE OF CERTAIN FACTORS ON NODULE PRODUCTION

The literature on the general subject of legume inoculation is very extensive; yet knowledge concerning the factors that influence nodule production is suprisingly meager. For the most part the investigations on this point are incidental and fragmentary. It has been shown by various investigators, however, that the nature of the medium in which the plant is grown has an influence on the production of nodules.

Rautenberg and Kühn (1864) grew *Vicia faba* in various nutrient solutions, and incidentally observed that in the nitrogen-free solution the beans developed an abundance of nodules, while in the solutions containing nitrogen no nodules were produced.

Hugo de Vries (1877) made a similar observation. He grew red clover in nutrient solutions, and the plants developed a large number of nodules in the nitrate-free solution but only a few or no nodules in the solution containing nitrates.

Vines (1888–1889) tested the influence of potassium nitrate on nodule development on *Vicia faba* grown in nutrient solutions and also in the soil. His experiments showed that potassium nitrate tends to inhibit nodule development, both in soil and water cultures.

Frank (1889) grew lupines and peas in humus soil and in humus-free soil. He found that the plants grown in the humus-free soil developed an abundance of nodules, and those grown in the soil rich in humus had no nodules. He offered the following explanation for this: " The lupines, and also the peas, obtain the same benefit from the nodule fungus as they do from the humus. Where humus is present, the plants prefer to obtain the nourishment from the humus and no nodules are developed; where humus is wanting, however, the nodule fungus infects the plants."[4]

[4] Translation from the original German.

Hiltner (1900) showed that the addition of potassium nitrate to the nutrient solution in which legumes are grown has an injurious influence on nodule development, and he thinks this is due to the fact that the formation of bacteroids in the small nodules is hastened by the presence of the nitrate. He considers the bacteroids as degenerate and inactive forms of the nodule-forming organism.

A somewhat more extensive investigation of this subject was undertaken by Nobbe and Richter (1902). They attempted to determine the influence of potassium nitrate and of humous substances on the fixation of nitrogen by soy beans. They grew the plants in flowerpots in a rich soil and in a poor soil. For rich soil they used garden soil. The poor soil was prepared by mixing 4000 grams of sand and 2500 grams of garden soil. Potassium nitrate was added to the poor soil in the proportions of 500 and 1000 milligrams to 6500 grams of the soil. When the plants were harvested the total amount of dry substance and of nitrogenous matter was determined in each plant. The results of this experiment show that the function of the nodules for nitrogen fixation is injured to a high degree by the presence of potassium nitrate. The influence of humous substances is similar, but not so great.

The observation made by Frank, by Nobbe and Richter, and by others — namely, that soil rich in humous substances has a deleterious effect on nodule development — was confirmed also by Moore (1905). He grew soy beans in rich nitrogenous soil, in poor clay soil, and in poor sandy soil. Very few nodules developed on the soy beans grown in rich soil, while in the poor clay soil and in the poor sandy soil the plants developed an abundance of nodules.

The development of nodules may also be affected by other agencies. Gain (1893) attempted to determine the influence of moisture on nodule development on *Pisum sativum*, two varieties of *Lupinus albus*, and *Faba vulgaris*. He grew the plants in a field located in a region where rain was very scarce during the early part of the summer. One-half of the plat planted with each legume was watered artificially, and the other half was exposed to drought. Examination of the plants showed that the plants watered artificially had five and one-half times as many nodules as those not watered.

Marchal (1901) determined the influence of fifteen different nutritive mineral salts on nodule development on peas grown in Sachs' nutrient

solution. He concluded from his experiments that nodule development is inhibited by the addition of the following nutrient salts in the given concentrations:

Alkaline nitrates, concentration 1 to 10,000
Ammonium salts, concentration 1 to 2,000
Potassium salts, concentration 1 to 300
Sodium salts, concentration 1 to 200

The influence of phosphates was variable, and calcium and magnesium salts stimulated nodule development. Marchal was of the opinion that the variation of the osmotic pressure, due to the presence of the different salts, may be the cause of this phenomenon.

Moore (1905) states that the addition of 1 per cent of sodium and potassium salts often entirely inhibits the formation of nodules, and smaller quantities considerably reduce their formation. The addition of calcium and magnesium salts, on the other hand, greatly favors nodule formation. Moore states further that this is not true with all the legumes, since the addition of calcium and magnesium carbonates is injurious to the formation of nodules on lupines and other plants adapted to acid soil.

In the following experiments the influence of various factors on nodule production has been investigated. The factors studied are light and darkness, aëration, moisture, various concentrations of nutrient solutions, and a considerable number of chemical substances.

EXPERIMENT 1

INFLUENCE OF AËRATION IN LIGHT AND IN DARKNESS

In this experiment Canada field peas were grown in an aqueous soil extract. The extract was prepared by taking one part of soil and four parts of water, by weight. The mixture was allowed to stand for two hours, and the liquid was then decanted and filtered. Twelve Erlenmeyer flasks of 300 cubic centimeters capacity were filled, and one pea was planted in each flask. Six of the flasks were covered with black paper and the other six were exposed to diffused light. Three flasks n each of the two series were aërated by passing a current of air through the liquid during the entire experiment. All the plants were inoculated with

a pure culture of *Bacillus radicicola*. After twenty-four days the plants were examined for nodules.

Results

All the plants developed plenty of nodules. The inoculation with the pure culture had no apparent effect on the number of nodules. The soil extract was not sterilized and apparently had plenty of the organisms. The plants whose roots were kept in darkness had a greater abundance of nodules than those whose roots were exposed to light. The aëration as supplied in this experiment had no stimulative effect on either the number or the size of the nodules.

EXPERIMENT 2

INFLUENCE OF SOME NUTRIENT SOLUTIONS IN LIGHT AND IN DARKNESS

Ninety Erlenmeyer flasks of 300 cubic centimeters capacity were divided into five series, with eighteen flasks in each series. These flasks were filled with the following solutions, respectively: series 1, with medium 101; series 2, with Crone's solution; series 3, with Pfeffer's solution; series 4, with tap water; series 5, with soil extract (the same as was used n experiment 1). Six flasks from each series, three covered with black paper and three not covered, were inoculated with a pure culture of *Bacillus radicicola*. A second group of six flasks from each series were prepared in the same manner, but each flask was inoculated with 5 cubic centimeters of soil extract. A third group of six flasks from each series were prepared in the same manner but were not inoculated. One plant was grown in each flask. The water of transpiration was replaced each week. At the end of four weeks the plants were examined for nodules. The results are given in table 2.

Results

Not all the plants that were inoculated developed nodules. A few nodules developed on the plants grown in medium 101, in Crone's solution, and in Pfeffer's solution. In the soil extract all the plants developed nodules, although the plants grew better in Crone's solution and in Pfeffer's solution. In the tap water no nodules developed. More nodules developed on the roots kept in darkness than on those exposed to the light.

TABLE 2. INFLUENCE OF SOME NUTRIENT SOLUTIONS ON NODULE DEVELOPMENT

Culture solution*	Treatment	Exposure	Number of nodules		
			Plant 1	Plant 2	Plant 3
Medium 101	Inoculated with *B. radicicola*	Light	None	None	None
		Dark	None	None	None
	Inoculated with soil extract	Light	None	None	None
		Dark	None	None	Few
	Not inoculated	Light	None	None	None
		Dark	None	None	None
Crone's solution	Inoculated with *B. radicicola*	Light	None	None	None
		Dark	Few	Few	Few
	Inoculated with soil extract	Light	None	None	None
		Dark	Few	Few	Few
	Not inoculated	Light	None	None	None
		Dark	None	None	None
Pfeffer's solution	Inoculated with *B. radicicola*	Light	None	None	None
		Dark	None	None	Few
	Inoculated with soil extract	Light	None	Few	Few
		Dark	None	Few	Few
	Not inoculated	Light	None	None	None
		Dark	None	None	None
Tap water	Inoculated with *B. radicicola*	Light	None	None	None
		Dark	None	None	None
	Inoculated with soil extract	Light	None	None	None
		Dark	None	None	None
	Not inoculated	Light	None	None	None
		Dark	None	None	None
Soil extract	Inoculated with *B. radicicola*	Light	Present	Present	Present
		Dark	Present	Present	Present
	Not inoculated	Light	Present	Present	Present
		Dark	Present	Present	Present

* See page 11.

EXPERIMENT 3

INFLUENCE OF POTASSIUM NITRATE IN LIGHT AND IN DARKNESS

In this experiment twelve glass cylinders, each of 5 liters capacity and 50 centimeters in height, were used. Six of these were filled with Crone's full nutrient solution, and the other six were filled with the same solution except that potassium chloride was substituted in place of potassium nitrate. Five plants were grown in each cylinder. The experiment was arranged in the following manner:

Series 1. Three of the cylinders filled with Crone's full nutrient solution were covered with black paper. Two of these were inoculated, and one was not inoculated.

Series 2. The other three cylinders filled with Crone's full nutrient solution were treated as was series 1, but were not covered with black paper.

Series 3. Three of the cylinders filled with Crone's solution in which potassium nitrate was replaced by potassium chloride, were covered with black paper. Two of these were inoculated, and one was not inoculated.

Series 4. The remaining three cylinders, with the same solution as was used for series 3, were treated as was series 3 but were not covered with black paper.

Results

When the plants were three weeks old, those grown in the solution with nitrate looked green and healthy, while those grown in the solution without nitrate were turning yellow and the lower leaves were dropping off. No difference in appearance was observed between the inoculated and the uninoculated plants. The uninoculated plants had no nodules; those grown in the presence of nitrate and inoculated had one or two nodules each; those grown in nitrate-free solution had about fifteen nodules each. Six weeks after planting, the plants grown in nitrate solution had thick, green leaves and thick roots, and no more nodules had developed on the inoculated plants. The plants grown in nitrate-free solution were yellowish except for the upper leaves, which were green; the roots were longer and more abundant than on the plants grown in nitrate solution. Nodules were abundant, continually developing on the new roots. The uninoculated plants in nitrate-free solution had no nodules and were practically dead.

The plants grown in nitrate-free solution with their roots exposed to light were slightly shorter than, and did not have quite as many nodules as, those grown in the same solution but with their roots kept in darkness. In the presence of the nitrate the development of certain green algæ interfered somewhat with root growth.

EXPERIMENT 4

INFLUENCE OF POTASSIUM NITRATE AND CALCIUM NITRATE IN PFEFFER'S SOLUTION

The procedure in this experiment was the same as in experiment 3. Only one plant was grown in each cylinder. Calcium nitrate was replaced by calcium chloride, and potassium nitrate was replaced by potassium chloride. The plants were kept until they began to blossom.

Results

In the solution with the nitrates, two or three nodules developed on each plant within twelve days after inoculation. No more nodules developed after that. In the cylinders not covered with black paper, algæ developed in abundance, and, surrounding the roots, dwarfed the plants. In the cylinders covered with black paper, also, some algæ developed in time, but they were far less abundant.

In the nitrate-free solution there was an abundant development of nodules. The nodules were more numerous on the plants grown in the cylinders covered with black paper than on those the roots of which were exposed to light. The root system of the plants grown in the nitrate-free solution was more developed than that of the plants grown in the nitrate solution.

An interesting point observed in this experiment and in experiment 3 was that the nodules developed, both in the nitrate solution and in the nitrate-free solution, immediately after inoculation. In the nitrate solution, however, no further development of nodules took place, while in the nitrate-free solution there was a continual development of new nodules on the new rootlets as time went on. This would seem to indicate either that the nodule-forming organisms were made inactive by the nature of the solution, or that the solution in some way affected the resisting power of the plants.

EXPERIMENT 5

INFLUENCE OF VARIOUS CONCENTRATIONS OF PFEFFER'S SOLUTION, BOTH WITH AND WITHOUT NITRATES

Wide-mouth bottles of 500 cubic centimeters capacity were used in this experiment. They were all covered with black paper. Two series were prepared, one with Pfeffer's full nutrient solution and the other with Pfeffer's solution in which the nitrates were replaced by the chlorides of the same metals. The following concentrations in each series were employed, taking the concentration of the full nutrient as 1: $\frac{1}{16}$, $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$, 1, 2, 3, 4, and 8. Five plants were grown in each bottle, and all were inoculated. The duration of the experiment was three weeks.

Results

In the full nutrient solution a few nodules developed in the $\frac{1}{16}$ concentration. In the other concentrations no nodules appeared within the three weeks.

In the nitrate-free solution nodules developed best in concentration 1. In the $\frac{1}{2}$ and $\frac{1}{4}$ concentrations a few nodules appeared.

EXPERIMENT 6

INFLUENCE OF PFEFFER'S SOLUTION IN WHICH THE ESSENTIAL ELEMENTS WERE ABSENT

In this experiment the same vessels were used as in experiment 5. The solutions were prepared as follows:

For solution minus nitrogen $\begin{cases} Ca(NO_3)_2 \text{ was replaced by } CaCl_2 \\ KNO_3 \text{ was replaced by } KCl \end{cases}$

For solution minus potassium $\begin{cases} KNO_3 \text{ was replaced by } NaNO_3 \\ KH_2PO_4 \text{ was replaced by } NaH_2PO_4 \\ KCl \text{ was replaced by } NaCl \end{cases}$

For solution minus phosphorus, KH_2PO_4 was replaced by NaH_2PO_4
For solution minus sulfur, $MgSO_4$ was replaced by $MgCl_2$
For solution minus magnesium, $MgSO_4$ was replaced by $MgCl_2$
For solution minus iron, $FeCl_3$ was replaced by NaCl

One plant was grown in each bottle. The plants were examined three weeks after planting.

Results

Nodules developed only in the nitrate-free solution. The plants in most of the solutions in this experiment and in experiment 5 did not grow well and normally. It is possible that slightly different results might have been obtained had the length of time of the experiment been extended. It was observed, however, in these and in the other experiments, that the number and the size of the nodules on a plant are influenced by the rate and the amount of growth of the plant. In other words, any disturbing factor in the normal functions of a plant tends to hinder the development of nodules.

EXPERIMENT 7

INFLUENCE OF MOISTURE

In experiments 7, 8, and 9, the plants were grown in glass tumblers. In each tumbler was placed 300 grams of air-dry sandy soil containing less than 0.5 per cent of moisture. The following percentages of moisture were used: 5, 10, 15, 20, 25, 30, 40, 50, and 60, the percentage being based on the air-dry soil. Three tumblers were used for each percentage of moisture, and five plants were grown in each tumbler. The plants were kept in the greenhouse. They were watered every other day, the necessary amount of water to be added being determined by weighing. The soil is naturally well inoculated with the Canada field pea organism, but in addition to this each tumbler was inoculated with a pure culture of the organism. The duration of the experiment was four weeks.

Results

The best growth took place in 15, 20, and 25 per cent of moisture. In 5 and 10 per cent of moisture the plants grew very slowly, while in 50 and 60 per cent the roots rotted. Nodules were present on all the plants. The number of the nodules on each plant increased with the percentage of moisture up to 40 per cent. These results agree with those of Gain (1893), who found that a larger number of nodules develop when the plants are abundantly watered.

EXPERIMENT 8

INFLUENCE OF CERTAIN SUBSTANCES IN VARYING QUANTITIES

The same soil and the same kind of vessels were used in this experiment as in experiment 7. Three hundred grams of the air-dry soil was in-

troduced into each glass tumbler; the substance to be tested was dissolved in the proper quantity of water, and this was added to each tumbler. Five plants were grown in each tumbler, and all the cultures were made in triplicate and were inoculated. The plants were allowed to grow for four weeks. The kind and the amount of the substance added, together with the results, are given in table 3:

TABLE 3. INFLUENCE ON NODULE DEVELOPMENT OF CERTAIN SUBSTANCES IN VARYING QUANTITIES

Substance used	Quantity added to 300 grams of soil (grams)	Condition of plants	Nodule development
KNO_3	0.25	Good growth	No nodules
	0.50	Poor growth	No nodules
	1.00	No growth	No nodules
	2.00	No growth	No nodules
$Ca(NO_3)_2$	0.25	Good growth	Few nodules
	0.50	Poor growth	No nodules
	1.00	No growth	No nodules
	2.00	No growth	No nodules
$MgSO_4$	0.25	Good growth	Nodules abundant
	0.50	Good growth	Nodules abundant
	1.00	Good growth	Nodules abundant
	2.00	Good growth	Nodules abundant
KH_2PO_4	0.25	Good growth	Nodules abundant
	0.50	Good growth	Nodules abundant
	1.00	Good growth	Nodules abundant
	2.00	Good growth	Nodules abundant
$CaCO_3$	0.25	Good growth	Nodules very abundant
	0.50	Good growth	Nodules very abundant
	1.00	Good growth	Nodules very abundant
	2.00	Good growth	Nodules very abundant
NH_4Cl	0.25	No growth	No nodules
	0.50	No growth	No nodules
	1.00	No growth	No nodules
	2.00	No growth	No nodules
$FeCl_3$	0.25	No growth	No nodules
	0.50	No growth	No nodules
	1.00	No growth	No nodules
	2.00	No growth	No nodules

TABLE 3 (*concluded*)

Substance used	Quantity added to 300 grams of soil (grams)	Condition of plants	Nodule development
Witte's peptone	0.25	Fair growth	Few nodules
	0.50	Poor growth	No nodules
	1.00	Poor growth	No nodules
	2.00	Poor growth	No nodules
Cane sugar	0.25	Good growth	Nodules present
	0.50	Good growth	Nodules present
	1.00	Good growth	Nodules present
	2.00	Good growth	Nodules present
	4.00	Poor growth	Nodules present
	8.00	Poor growth	No nodules
	16.00	Very poor growth	No nodules
Controls	Nothing added	Good growth	Nodules present

Results

The addition of $MgSO_4$, KH_2PO_4, and $CaCO_3$ in the concentrations used in the experiment had a beneficial effect on the development of nodules. Cane sugar at low concentrations had apparently no effect. At the concentrations of 4, 8, and 16 grams of sugar in 300 grams of soil, cane sugar was injurious, probably due to fermentation products and to stimulation of the development of microorganisms injurious to the plants and also to the development of nodules. The addition of NH_4Cl and $FeCl_3$ completely inhibited the growth of the plants. In the case of KNO_3 and $Ca(NO_3)_2$ the concentration of $\frac{1}{4}$ gram in 300 grams of soil had a beneficial effect on the growth of the plant, but an injurious effect on the development of nodules. A few nodules developed in the presence of $Ca(NO_3)_2$, but none in the presence of KNO_3. The higher concentrations of $Ca(NO_3)_2$ and KNO_3 inhibited nodule development and also caused injury to the plants.

EXPERIMENT 9

INFLUENCE OF CERTAIN ADDITIONAL SUBSTANCES

The method used in this experiment was the same as in experiment 8. Several additional chemicals were tested. In examining the plants, the

number of nodules was counted and both the total number of nodules and the average per plant for each concentration of the substance were calculated. The results follow in table 4:

TABLE 4. INFLUENCE OF CERTAIN ADDITIONAL SUBSTANCES ON NODULE DEVELOPMENT

Chemical used	Quantity added to 300 grams of soil (grams)	Number of plants	Condition of plants	Number of small nodules	Number of large nodules	Total number of nodules	Number of nodules per plant
$Ca(NO_3)_2$	0.25	10	Small	6	......	6	0.6
	0.50	8	Small	......	......	0	0
	1.00	0	Plants killed	......	......	......	....
	2.00	0	Plants killed	......	......	......	....
Tannic acid	0.25	11	Good	40	138	178	16.2
	0.50	8	Good	50	41	91	11.4
	1.00	12	Good	17	50	67	5.6
	2.00	13	Good	100	20	120	9.2
KH_2PO_4	0.25	6	Good	10	50	60	10.0
	0.50	7	Good	50	58	108	15.4
	1.00	4	Small	30	10	40	10.0
	2.00	4	Small	16	5	21	5.3
$MgSO_4$	0.25	14	Good	46	100	146	10.4
	0.50	11	Good	26	50	76	6.9
	1.00	12	Good	60	41	101	8.4
	2.00	13	Good	24	32	56	4.3
KCl	0.25	7	Small	34	12	46	6.6
	0.50	0	Plants killed	......	......	......	....
	1.00	0	Plants killed	......	......	......	....
	2.00	0	Plants killed	......	......	......	....
KNO_3	0.25	14	Good	15	0	15	1.1
	0.50	14	Small	......	......	......	....
	1.00	3	Plants killed	......	......	......	....
	2.00	0	Plants killed	......	......	......	....
NH_4Cl	0.25	12	Good	0	0	0	0
	0.50	2	Small	0	0	0	0
	1.00	0	Plants killed	......	......	......	....
	2.00	0	Plants killed	......	......	......	....
Witte's peptone	0.25	11	Good	21	8	29	2.6
	0.50	11	Good	20	2	22	2.0
	1.00	9	Small	4	0	4	0.4
	2.00	1	Very small	......	......	......	....

TABLE 4 (*concluded*)

Chemical used	Quantity added to 300 grams of soil (grams)	Number of plants	Condition of plants	Number of small nodules	Number of large nodules	Total number of nodules	Number of nodules per plant
KOH	0.25	12	Good	35	50	85	7.1
	0.50	10	Good	10	45	55	5.5
	1.00	3	Small	11	25	36	12.0
	2.00	0	Plants killed	......	......	......	....
$Fe(NO_3)_3$	0.25	11	Good	4	0	4	0.4
	0.50	14	Good	1	0	1	0.1
	1.00	6	Small	0	0	0	0
	2.00	0	....	......	......	......	....
$Ca(H_2PO_4)_2$	0.25	8	Good	6	45	51	6.4
	0.50	14	Good	90	94	184	13.1
	1.00	12	Good	54	60	114	9.5
	2.00	5	Small	8	11	19	3.8
$CaSO_4$	0.25	11	Good	22	65	87	7.9
	0.50	10	Good	15	60	75	7.5
	1.00	14	Good	57	50	107	7.4
	2.00	10	Good	21	45	66	6.6
$FeCl_3$	0.25	0	Plants killed	......	......	......	....
	0.50	0	Plants killed	......	......	......	....
	1.00	0	Plants killed	......	......	......	....
	2.00	0	Plants killed	......	......	......	....
Starch	1.00	12	Good	40	82	122	10.2
	2.00	13	Good	59	40	99	7.6
	4.00	8	Good	18	42	60	7.5
Controls	....	18	Good	......	......	113	6.3
	....	14	Good	......	......	107	7.6

Results

The results of experiment 9 are similar to those of experiment 8. The following chemicals added to the soil at the concentrations used in the experiment were injurious to the plants and tended to inhibit the development of nodules: $Ca(NO_3)_2$, KCl, KNO_3, NH_4Cl, Witte's peptone, $Fe(NO_3)_3$, and $FeCl_3$. On the other hand, tannic acid, KH_2PO_4, $MgSO_4$, KOH, $Ca(H_2PO_4)_2$, $CaSO_4$, and starch exerted a beneficial influence on nodule development and appeared to have no injurious effect on the plants.

GENERAL DISCUSSION OF RESULTS OF EXPERIMENTS

The nine experiments reported in Part II, on the factors affecting the development of nodules on Canada field peas, are not extensive enough to allow any broad and general deductions, but the results point to several conclusions. Nodules develop readily on Canada field peas in nutrient solutions, provided the proper nutrient salts are added. Varying the concentration appears to have a marked influence on nodule development. Aëration has no appreciable effect. Nodules developed on the long roots at as great a depth as 30 centimeters below the surface of the nutrient solution. If air is essential for the development of nodules, enough of it was dissolved in the nutrient solution under the conditions in the experiments. The presence of nitrates in the nutrient solution or in the soil tends to inhibit the development of nodules; the reason for this is not known. If the plants are grown in the presence of nitrates for about a week and then inoculated, a few nodules will develop, but no further development of nodules takes place; in water cultures without nitrates and inoculated, a continuous nodule development takes place as long as the roots grow.

The chemical composition of the various soils used for agricultural purposes differs. What influence this has on the various groups of the nodule-forming organism and on nodule development has never been extensively investigated. The results of the foregoing experiments emphasize its importance. The limited distribution of the different groups of the nodule-forming organism in some soils, the failures in inoculations, and the difficulty in growing certain legumes, may be explained in certain cases as being due to the composition of the soil. It is known that the addition of lime to certain soils has a beneficial effect on nodule development and on the growth of some legumes. It is highly probable that the addition of other substances to the soil may be beneficial to other legumes.

PART III. INFLUENCE OF VARIOUS MEDIA ON THE INFECTING POWER AND THE VITALITY OF BACILLUS RADICICOLA

As indicated previously, and again further developed in the discussion of this subject, the view has been maintained that the infecting power, or "virulence," of the nodule-forming organism may be impaired by cultivating it on certain media. In order to determine whether or not

such is the case, and also to determine the media most favorable for maintaining the vitality of the organism, the following experiments were made.

The term *virulence* has been used by previous investigators to mean the ability of the organism to penetrate the root and produce nodules. Since the term *virulence* in this connection, as also suggested by Edwards (in Marshall's Microbiologie), does not correctly apply to the legume bacteria, the term *infecting power* will be used throughout this paper.

Beyerinck (1890) was the first to isolate a pure culture of an organism from a nodule. Prazmowski (1890), Frank (1889), and Nobbe and others (1891), stimulated by Beyerinck's success, were also able to obtain pure cultures from the nodules of various legumes, and to produce nodules by inoculating the plants with the pure cultures. The experiments on the inoculation of legumes by pure cultures at once raised a question as to the classification of the nodule-forming organism, which question is intimately connected with the subject of the infecting power of the organism and the resistance of the plants. Do all the different organisms from the various species of legumes belong to several species, or do they belong only to one species but to several races or varieties? Can the organism from one species of legumes cause nodules on a different species of legumes? Is the relation between the legume and the organism a case of symbiosis or a case of parasitism? Does the organism have the biological or physiological character called *virulence* as understood by pathologists, and can this be altered or destroyed without injuring or destroying the other physiological activities? Do the host plants have a resistance in a pathological sense, and can this resistance be altered by the environmental factors without altering the morphology, the structure of the tissues, and the physiological activities of the plants? Is the resistance against the entrance of the organism into the root tissues different from the resistance against the development of the organism inside the root tissues? These and similar questions formed the foundation of the numerous investigations that were undertaken subsequently to the isolation of the pure culture of the nodule-forming organism, and nodule production by pure cultures.

Even before the isolation of the nodule-forming organism by Beyerinck, it was observed by Hellriegel (1886) that when peas, vetch, beans, clover, serradella, and lupines were inoculated with an infusion from the same

soil, all the plants developed nodules except the serradella and the lupine. From this Hellriegel inferred that important differences must exist between the nodule bacteria of the different legumes.

Beyerinck (1888) was of the opinion that the nodule-forming organisms of the legumes belonged to one species, but that there were several groups and in each group a number of varieties. From the results of his subsequent investigation (1890) he was forced to change his former opinion. He considered the organism of Ornithopus and that of Vicia to be two distinct species.

Frank's investigations (1899) led him to believe that there was only one species among the nodule-forming organisms.

Salfeld (1888) grew peas and horse beans in "Hochmoorboden," and inoculated one part of them with sandy soil in which peas were grown and the other part with sandy soil in which lupines were grown. Both the peas and the horse beans inoculated with the pea soil developed nodules, while those inoculated with the lupine soil were free from nodules.

Laurent (1901) could produce nodules on dwarf peas by inoculating them with material from nodules of thirty different leguminous species, but he claimed that the number, size, and appearance of the nodules was influenced by the inoculating material of the different sources.

Kirchner (1896) grew about one hundred different species of legumes in the Hohenheimer botanical garden. He observed that all the different species of legumes developed nodules in the garden soil except the soy beans, although these had been grown in the garden for ten years. The soy beans did not produce nodules until they were inoculated with soil on which Japanese soy beans had been grown.

The investigations of Mazé (1898) led him to divide the nodule-forming organisms into two groups — those adapted to a neutral or an alkaline soil, and those adapted to an acid soil; the former infecting the plants that favor neutral and alkaline soil, and the latter infecting the plants that favor acid soil.

Nobbe, Schmid, Hiltner, and Hotter (1891) undertook a very extensive series of investigations on the general subject of nitrogen assimilation by leguminous plants. Much of the present information on this subject is due to these men, especially to Hiltner and Nobbe. They showed that the only way to study the relations between the nodule-forming organisms of the different legumes and the different species and varieties of legumes

was to use pure cultures of the organisms for inoculation purposes, and not the soil infusions as was done by a number of previous investigators.

In a subsequent paper, Nobbe, Hiltner and Schmid (1895) arrived at the following important conclusions on the relation of nodule-forming organisms to the different species of legumes:

"The infecting power of the nodule bacteria of the various groups and species of legumes cannot be differentiated absolutely, but only in degree. The pure cultures from nodules of different species of legumes do not represent different species, but only different forms. We have not the least doubt that all the nodule bacteria of the different legumes we have studied, even those of Mimosæ, are one species, all belonging to *Bacillus radicicola* of Beyerinck. These bacteria, however, are influenced by the plants in whose roots they live to such a degree that their descendants are able to infect readily only that species of legumes to which the former host plant belonged, at the same time losing partly or completely the power to infect other species of legumes. When the legume is grown in a suitable soil, nodules will develop on the roots only when either those nodule bacteria are present which have lived previously on that legume species, or when the neutral nodule bacteria are present. The latter will be found in the soil where legumes have never been grown or where they have not been grown for a long time. If one legume is preponderantly grown in a soil, most of the neutral bacteria become influenced by this legume, and when a different legume is planted which is not closely related to the former no nodules will be formed, or only very few and faulty ones, and these will appear so late that they will be of very little value to the plants."[5]

By means of extensive experiments (Nobbe and Hiltner, 1896) it has been demonstrated that effective inoculation is obtained only when the plants are inoculated with bacteria from the nodules of the same species of legumes.

Moore (1905) conducted extensive cross-inoculation experiments, and maintains that "it is possible to cause the formation of nodules upon practically all legumes, no matter what was the source of the original organisms, provided they were cultivated for some time upon a synthetic nitrogen-free medium." He states further: "It is undoubtedly true that the long adaptation of the bacteria to the special conditions obtaining

[5] Translation from the original German.

in a particular species of legume enables such organisms to produce more abundant nodules in a shorter length of time than bacteria isolated from some other legume and grown upon nitrogen-free media. While this is of considerable practical importance, and will probably always make it necessary to distribute the specific organism for the specific crop, it does not in any way indicate that the bacteria found in the nodules of beans, peas, clovers, etc., are separate species. The most that can be maintained is that there is a slight physiological difference due to the long association with a plant of a peculiar reaction which enables the bacteria more easily to penetrate the host upon which they have been accustomed to grow. These slight racial characteristics can readily be broken down by cultivation in the laboratory, and it is entirely possible to secure a universal organism capable of producing a limited number of nodules upon all the legumes which now possess these growths."

Hopkins (1904) found that the organism from sweet clover readily inoculates alfalfa.

Nobbe and Hiltner (1900) undertook to train the nodule-forming organism of peas and that of beans so that the former may cause nodules on beans and the latter on peas. They succeeded in doing this, and drew the following conclusions:

1. The nodule-forming organism from peas can be trained to produce nodules on beans, and that from beans to produce nodules on peas.

2. Although some nodules are produced in both cases, the organisms do not assimilate any nitrogen at first.

3. If the pea organism that caused nodules on beans is isolated and beans are inoculated with it a second time, the organism then infects the beans more readily than at the first inoculation and its power to assimilate nitrogen is increased. The organism of beans behaves in the same manner when made to infect peas.

Kellerman (1912) reports that Mr. Leonard has succeeded in securing abundant inoculation on soy beans, lupines, and alfalfa from an organism of a culture originally isolated from the alfalfa nodule and kept on an artificial medium in the laboratory for about six years. Kellerman, therefore, is of the opinion that the nodule-forming organisms of all the Leguminosæ should be considered as a single species.

The evidence from the investigations mentioned above points to two conclusions: (1) that, with some exceptions, the nodule-forming organism

from one legume does not cause nodules on another legume; (2) that the organism from one legume may be trained to cause nodules on any other legume. The evidence for the latter conclusion, however, is not final.

About 1895 a German company placed nitragin on the market — a pure culture of the nodule-forming organism for inoculation purposes. The cultures were propagated on gelatin and their preparation was based on the results of the investigations of Nobbe and Hiltner. These cultures were extensively tested both in Germany and in other countries, and, as judged by the reports of these tests, the cultures proved only partially successful. As a result of these adverse reports on nitragin, Nobbe and Hiltner (1899 a) undertook to ascertain the cause of the low efficiency of their cultures. They had already shown that the nodule-forming organism can be trained to infect other legume species than that of its host plant, when they trained the organism from peas to produce nodules on beans and that from beans to cause nodules on peas. They went a step further and demonstrated that the infecting power of the organisms can be altered in degree. They stated that the propagation of the organism on artificial media increases or diminishes the vitality, and that in general nitrogenous media are injurious to the vitality of the organism.

Moore (1905) also reports that as a result of numerous trials it has been found that, although the bacteria increase most rapidly on a medium rich in nitrogen, the resulting growth is usually of very much reduced vitality, and when put into the soil these organisms have lost the ability to break up into the minute forms necessary in order to penetrate the root hairs.

In a further study of this subject, Hiltner (1900) was led to believe that this variableness in the infecting power of the nodule-forming organism is the determining factor of the number and size of the nodules on every plant when grown under otherwise favorable conditions. He took some older plants that already had nodules on their roots, and placed them in a nutrient solution without any nitrogen. Repeated inoculation with its own organism did not produce any nodules on the new rootlets. When fall came, and the leaves began to turn yellow and drop, and the organisms in the nodules became weaker than those in the solution, nodules began to develop on the rootlets. When Hiltner took older

plants that had no nodules on their roots and placed them in a similar solution to that used with the other plants, an immediate development of nodules took place on the new rootlets. From this and other experiments, Hiltner concluded that "the active nodules produce immunity in the plant against the bacteria that possess the same or a lower degree of infecting power than those already living in the nodules of that plant. Only bacteria of higher infecting power are able to enter the root tissue."[6]

Süchting (1904), believing that Hiltner's theory of the infecting power of the organism and its relation to nodule development was not sound, undertook a series of interesting experiments on this subject, as well as an elaborate discussion of Hiltner's theory and of his own theory. In his experiments Süchting attempted to ascertain three points: (1) Have the organisms that produce the first nodules on the plant less infecting power than those that produce nodules on the same plant subsequently? (2) Does the symbiosis with the plant influence the infecting power of the organism? (3) Does the artificial medium influence the infecting power of the organism?

From his experiments Süchting drew the following conclusions:

1. The infecting power of the bacteria is not proportional to the age of the nodule.

2. The passage of the bacteria through the host plant does increase their infecting power. Their infecting power does not vary at the different stages of the plant's vegetative period, and the feeding of the plant by potassium nitrate is injurious to the bacteria in the nodules.

3. When propagated on artificial media the lupine bacteria lose their infecting power on some media and may exist in a so-called pseudo form. On neutral media the bacteria retain their infecting power better than on acid media. The horse-bean bacteria do not behave in the same manner, but keep their infecting power for a long time on suitable media.

Lewis and Nicholson (1905), on the other hand, found by their experiments that "It seems that the presence or absence of nitrogen in the culture media is not the determining factor in maintaining the activity of the germ. Cultivation in the presence of the amount of nitrogen usually present in bouillon with from two to five per cent of cane sugar

[6] Translation from the original German.

or glucose, preferably the former, has given best results in all of the work connected with the experiment."

In the following pages data are presented on experiments conducted through several years in an attempt to alter the "virulence"— that is, the infecting power — of the organism. In experiments 10, 12, and 13, *Bacillus radicicola* of Canada field pea was used; in experiment 11 that of alfalfa was used. The organisms were propagated and kept on various media. Their infecting power was tested and measured by the nodule development in plants grown in a sterilized sandy soil.

EXPERIMENT 10

INFLUENCE OF CLAY, LOAM, SAND, AND CARBORUNDUM

In this experiment the organism was grown on clay, sandy loam, sandy soil, fine quartz sand, coarse quartz sand, and carborundum. One hundred grams of each substance, air-dried, was introduced into Erlenmeyer flasks of 300 cubic centimeters capacity. After sterilization the media were heavily seeded with *B. radicicola*. This was accomplished by introducing into each flask the growth of *B. radicicola* from one agar slope, along with the necessary quantity of water. The amount of moisture added to each medium was about five per cent less than its capacity for holding water.

Two series of flasks were prepared. In series 1 the media, as soon as seeded with the organism, were spread on sterile paper and allowed to dry at room temperature. The time required for their complete drying was about six hours. In series 2 the media were left in the flasks, plugged with cotton, and allowed to stand in the laboratory. Drying of the media in this series was very gradual. The infecting power of the organism in these cultures was tested by inoculating plants. For this purpose Canada field peas were grown in sterilized soil in flowerpots, and were inoculated with the respective cultures at the time of seeding. Inoculation was accomplished by scattering one gram of the inoculating material over the soil in the flowerpots. The first test was made when the cultures were ten days old and the second test when the cultures were forty-six days old. When the plants were three weeks old they were examined for presence of nodules. The results are presented in tables 5 and 6:

TABLE 5. RESULTS OF FIRST INOCULATION TEST. THE CULTURES WERE TEN DAYS OLD

	Plants inoculated with	Number of plants	Number of plants with nodules	Total number of nodules	Number of nodules per plant
Series 1	Clay	17	4	31	1.8
	Sandy loam	23	13	81	3.5
	Sandy soil	14	7	45	3.2
	Fine quartz sand	15	3	9	0.6
	Coarse quartz sand	19	0	0	0
	Carborundum	11	2	25	2.3
Series 2	Clay	10	6	51	5.1
	Sandy loam	15	10	90	6.0
	Sandy soil	18	10	67	3.7
	Fine quartz sand	13	7	92	7.1
	Coarse quartz sand	18	12	94	5.2
	Carborundum	14	4	23	1.6
	Agar slope culture	19	15	90	4.7
	Controls	13	3	15	1.2

TABLE 6. RESULTS OF SECOND INOCULATION TEST. THE CULTURES WERE FORTY-SIX DAYS OLD

	Plants inoculated with	Number of plants	Number of plants with nodules	Total number of nodules	Number of nodules per plant
Series 1	Clay	5	5	53	10.6
	Sandy loam	12	11	79	6.6
	Sandy soil	12	10	151	12.6
	Fine quartz sand	10	10	58	5.8
	Coarse quartz sand	4	4	41	10.3
	Carborundum	11	7	113	10.3
Series 2	Clay	3	3	20	6.7
	Sandy loam	4	3	45	11.3
	Sandy soil	14	14	188	13.4
	Fine quartz sand	8	7	190	23.8
	Coarse quartz sand	7	6	78	11.1
	Carborundum	10	4	32	3.2
	Controls	36	13	120	3.3

Results

In both tests there was a certain amount of infection due to other sources than the inoculating materials. In the first test three of the thirteen plants used as controls developed nodules, while in the second test thirteen of the thirty-six control plants developed nodules. It was noticed, however, that, as a rule, if contamination took place subsequently to the inoculation and the plants were examined within four weeks after planting, the nodules due to the contamination were small and developed on the lateral roots near the surface of the soil, whereas nodules resulting from inoculation always appeared first on the taproot and were larger. Nevertheless, the results as shown in the two tables do not allow any clear-cut deductions. The plants of the first test (table 5) were examined three weeks after planting; the plants of the second test (table 6) were kept for four weeks, which probably accounts for the larger number of nodules on those plants.

It appears certain that *B. radicicola* remained alive and retained its infecting power in practically all the substances for forty-six days. Carborundum gave the poorest results. The plants inoculated with this substance developed only small nodules, mostly on the side roots — a fact pointing to subsequent infection. As regards the two series, much better inoculation was obtained from series 2 in both tests. In the first test 99 plants were inoculated with the cultures of series 1. These plants produced 191 nodules, which is an average of 1.9 nodules per plant. The 88 plants inoculated with the cultures from series 2 produced 417 nodules, which is an average of 4.7 nodules per plant. From similar calculations for the second test, it is found that the average number of nodules per plant was 9.2 in series 1, and 12 in series 2. In both tests the plants inoculated with the cultures of series 2 produced more nodules than those inoculated with the cultures of series 1. The drying of the substances in series 1 either reduced the infecting power of *B. radicicola*, or reduced the number of the organisms, or had both results.

EXPERIMENT 11

INFLUENCE OF HYDROCHLORIC ACID, SODIUM HYDROXIDE, AND CANE SUGAR, IN VARYING CONCENTRATIONS

In this experiment *B. radicicola* of alfalfa was isolated and identified according to the procedure described in Part I of this paper. The

organism was propagated on media 334, 335, and 337 (page 11), to which were added various amounts of hydrochloric acid (HCl) and sodium hydroxide (NaOH). Cane sugar was added in various amounts to medium 334.

Ten cubic centimeters of the media were introduced into each test tube and sterilized. While the agar was still melted the various additions were made to the tubes, and, after thorough mixing, the tubes were sloped.

All cultures were made in duplicate. At the end of three weeks stain preparations were made from each slope for morphological study, carbol fuchsin being used for staining. The media employed and the results of the morphological study are given in table 7:

TABLE 7. MORPHOLOGICAL VARIATION OF B. RADICICOLA ON THE DIFFERENT MEDIA

Medium	Morphological appearance	Multiplication
Medium 334, 10 cc.		
+ 0	Small, short cells	Fair
+ 0.1 cc. N/1 HCl	Short rods, slightly stained	Fair
+ 0.5 cc. N/1 HCl	Short rods, slightly stained	Poor
+ 1.0 cc. N/1 HCl	Short rods, slightly stained	None
+ 1.5 cc. N/1 HCl	Short rods, slightly stained	None
+ 2.0 cc. N/1 HCl	Short rods, slightly stained	None
+ 3.0 cc. N/1 HCl	Short rods, slightly stained	None
+ 0.1 cc. N/1 NaOH	Short rods, well stained	Good
+ 0.5 cc. N/1 NaOH	Short rods, well stained	Good
+ 1.0 cc. N/1 NaOH	Short rods, well stained	Poor
+ 1.5 cc. N/1 NaOH	Short rods, well stained	Poor
+ 2.0 cc. N/1 NaOH	Short rods, well stained, few small bacteroids	Very poor
+ 3.0 cc. N/1 NaOH	Short rods, well stained, few small bacteroids	Doubtful
+ 0.1 per cent cane sugar	Cells vary in size, bacteroids present	Good
+ 0.5 per cent cane sugar	Cells vary in size, bacteroids present	Good
+ 1.0 per cent cane sugar	Cells vary in size, bacteroids present	Good
+ 1.5 per cent cane sugar	Cells vary in size, bacteroids present	Good
+ 2.0 per cent cane sugar	Cells vary in size, bacteroids present	Good
+ 3.0 per cent cane sugar	Cells vary in size, bacteroids present	Good
+ 4.0 per cent cane sugar	Cells vary in size, bacteroids more abundant	Good
+ 5.0 per cent cane sugar	Cells vary in size, bacteroids more abundant	Good
+ 6.0 per cent cane sugar	Cells vary in size, bacteroids more abundant	Fair
+ 8.0 per cent cane sugar	Cells vary in size, bacteroids very abundant	Fair
+ 10.0 per cent cane sugar	Cells vary in size, bacteroids very abundant	Poor

TABLE 7 (*concluded*)

Medium	Morphological appearance	Multiplication
Medium 335, 10 cc.		
+ 0	Variation in size and shape, few bacteroids	Good
+ 0.1 cc. N/1 HCl	Variation in size and shape, few bacteroids	Good
+ 0.5 cc. N/1 HCl	Very few rods	Poor
+ 1.0 cc. N/1 HCl	No organisms visible	Doubtful
+ 1.5 cc. N/1 HCl	No organisms visible	None
+ 2.0 cc. N/1 HCl	No organisms visible	None
+ 3.0 cc. N/1 HCl	No organisms visible	None
+ 0.1 cc. N/1 NaOH	Variation in size and shape, few bacteroids	Very good
+ 0.5 cc. N/1 NaOH	Variation in size and shape, few bacteroids	Very good
+ 1.0 cc. N/1 NaOH	Greater variation, more bacteroids than in 0.5	Good
+ 1.5 cc. N/1 NaOH	Greater variation, more bacteroids than in 0.5	Good
+ 2.0 cc. N/1 NaOH	Greater variation, more bacteroids than in 0.5	Poor
+ 3.0 cc. N/1 NaOH	Cells stained deeper than others, bacteroids present	Doubtful
Medium 337, 10 cc.		
+ 0	Pronounced variation in shape and size of cells.	Good
+ 0.1 cc. N/1 HCl	Small cells, irregular shape and size	Good
+ 0.5 cc. N/1 HCl	Very slender cells, irregular shape and size	Poor
+ 1.0 cc. N/1 HCl	Extremely small cells	Very poor
+ 1.5 cc. N/1 HCl	Extremely small cells	Doubtful
+ 2.0 cc. N/1 HCl	Extremely small cells	None
+ 3.0 cc. N/1 HCl	No organisms visible	None
+ 0.1 cc. N/1 NaOH	Short, irregular cells	Abundant
+ 0.5 cc. N/1 NaOH	Short, irregular cells	Abundant
+ 1.0 cc. N/1 NaOH	Shape and size extremely varied, many bacteroids	Abundant
+ 1.5 cc. N/1 NaOH	Large cells, varying in shape and size, many bacteroids	Good
+ 2.0 cc. N/1 NaOH	Large cells, varying in shape and size, many bacteroids	Good
+ 3.0 cc. N/1 NaOH	Very large cells, varying in shape and size, many bacteroids	Poor

In order to test the infecting power of the different cultures, three flowerpots of alfalfa plants grown in sterile soil were inoculated with the organism from each test tube. Four weeks after inoculation the plants were examined for nodule development. The results of the inoculations are presented in table 8. Fifty-eight plants in flowerpots were used as controls. These plants were grown in sterile soil and were not inoculated. The control plants were distributed among the other

plants in order to see to what extent an infection from neighboring flower-pots may take place.

TABLE 8. INFECTING POWER OF VARIOUS CULTURES. B. RADICICOLA WAS PROPAGATED FOR THREE WEEKS ON THE DIFFERENT MEDIA

Medium	Number of plants inoculated	Total number of nodules	Number of nodules per plant
Medium 334, 10 cc.			
+ 0	42	265	6.3
+ 0.1 cc. N/1 HCl	50	320	6.4
+ 0.5 cc. N/1 HCl	43	188	4.3
+ 1.0 cc. N/1 HCl	32	0	0
+ 1.5 cc. N/1 HCl	38	6	0.2
+ 2.0 cc. N/1 HCl	53	22	0.4
+ 3.0 cc. N/1 HCl	35	7	0.2
+ 0	37	184	5.0
+ 0.1 cc. N/1 NaOH	43	275	6.4
+ 0.5 cc. N/1 NaOH	48	234	4.9
+ 1.0 cc. N/1 NaOH	47	304	6.5
+ 1.5 cc. N/1 NaOH	34	168	4.9
+ 2.0 cc. N/1 NaOH	27	94	3.5
+ 3.0 cc. N/1 NaOH	27	75	2.8
+ 0.1 per cent cane sugar	46	182	4.0
+ 0.5 per cent cane sugar	35	124	3.5
+ 1.0 per cent cane sugar	32	117	3.7
+ 1.5 per cent cane sugar	48	198	4.1
+ 2.0 per cent cane sugar	38	140	3.7
+ 3.0 per cent cane sugar	29	125	4.3
+ 4.0 per cent cane sugar	35	138	3.9
+ 6.0 per cent cane sugar	33	132	4.0
+ 8.0 per cent cane sugar	33	110	3.3
+ 10.0 per cent cane sugar	30	85	2.8
Medium 335, 10 cc.			
+ 0	29	132	4.6
+ 0.1 cc. N/1 HCl	34	183	5.4
+ 0.5 cc. N/1 HCl	50	6	0.1
+ 1.0 cc. N/1 HCl	68	0	0
+ 1.5 cc. N/1 HCl	50	22	0.4
+ 2.0 cc. N/1 HCl	56	5	0.1
+ 3.0 cc. N/1 HCl	58	4	0.1
+ 0.1 cc. N/1 NaOH	33	186	5.6
+ 0.5 cc. N/1 NaOH	32	131	4.1
+ 1.0 cc. N/1 NaOH	30	212	7.1
+ 1.5 cc. N/1 NaOH	36	284	7.9
+ 2.0 cc. N/1 NaOH	30	180	6.0
+ 3.0 cc. N/1 NaOH	21	109	5.2

TABLE 8 (*concluded*)

Medium	Number of plants inoculated	Total number of nodules	Number of nodules per plant
Medium 337, 10 cc.			
+ 0	23	54	2.3
+ 0.1 cc. N/1 HCl	32	50	1.6
+ 0.5 cc. N/1 HCl	37	110	3.0
+ 1.0 cc. N/1 HCl	36	77	2.1
+ 1.5 cc. N/1 HCl	36	23	0.6
+ 2.0 cc. N/1 HCl	33	94	2.8
+ 3.0 cc. N/1 HCl	32	132	4.1
+ 0.1 cc. N/1 NaOH	26	80	3.1
+ 0.5 cc. N/1 NaOH	27	120	4.4
+ 1.0 cc. N/1 NaOH	39	174	4.5
+ 1.5 cc. N/1 NaOH	31	114	3.7
+ 2.0 cc. N/1 NaOH	32	154	4.8
+ 3.0 cc. N/1 NaOH	33	87	2.6
Controls	735	*624	0.8

* Nodules were present in only thirteen out of fifty-eight pots

Results

The extent of multiplication and the description of the morphological characters of the organisms in the various media are summarized in table 7. No visible increase in the number of organisms was found when 1 cubic centimeter or more of the normal solution of HCl was added to 10 cubic centimeters of each medium. The few organisms found on these slopes were probably those that were introduced when the slopes were inoculated. In medium 337 slight multiplication took place on slopes of 10 cubic centimeters of the medium plus 1 cubic centimeter of the normal solution of HCl. The best multiplication occurred in media 335 and 337 when 0.1 to 1 cubic centimeter of the normal solution of NaOH was added to 10 cubic centimeters of the medium. This was particularly noticeable in medium 337. The addition of 3 cubic centimeters of the normal solution of NaOH to 10 cubic centimeters of the medium practically inhibited multiplication. The bacteroids developed more readily when NaOH was added.

The addition of sugar to medium 334, up to 10 per cent, caused more rapid multiplication and also the development of bacteroids.

In medium 334 multiplication of the organisms was very slow and only a few bacteroids developed in the three weeks. In medium 337 multiplication was abundant and bacteroids developed.

The results of inoculation are given in table 8. There were two hundred and eight flowerpots, which were crowded together because of lack of space. Fifty-eight flowerpots contained control plants, which were scattered among the inoculated pots. The plants in forty-five of the control pots developed no nodules; thirteen of the control pots were contaminated, and these were located mostly among the flowerpots inoculated with the organisms grown on medium 337. This contamination occurred in spite of the precautions taken to prevent the organisms from being carried from one flowerpot to another when the plants were watered. In these experiments and in others not reported in this paper, it was found that when a large number of flowerpots were used at one time it was difficult to prevent infection from other sources than that of the inoculating material. This was particularly true in the case of those legumes that produce an abundance of nodules in the soil of this region, and when the plants were allowed to grow for longer periods than three weeks. The results in this experiment are marred by a certain amount of contamination. The data in table 8 are so arranged as to show the total number of nodules on all the plants inoculated with the same material, and also to show the average number of nodules to each of these plants. Basing the conclusions on the mere number of nodules overemphasizes the importance of the contamination. When the plants were examined, and the size, location, and evenness of distribution of the nodules among the plants in the same flowerpot were noted, in addition to their total number, much more reliable evidence was obtained. In view of this, the following conclusions seemed to be warranted:

When *B. radicicola* of alfalfa is propagated on media 334, 335, and 337 and kept for three weeks, multiplication of the organism takes place and the infecting power is not lost. A slight reduction in infecting power seems to be apparent on medium 337. The addition of 0.1 cubic centimeter of the normal solution of HCl to 10 cubic centimeters of each of these media very slightly diminished the amount of growth, but the infecting power was not affected. When 0.5 cubic centimeter of the acid solution

was added, the amount of growth was decidedly reduced on media 334 and 335 and the infecting power also was reduced. The influence of this amount of acid in medium 337 was not so pronounced. The addition of 1 cubic centimeter or more of the acid solution completely inhibited the growth and the infecting power of the organism on all three media.

The addition of 0.1, 0.5, 1, 1.5, and 2 cubic centimeters, respectively, of the normal solution of NaOH, to 10 cubic centimeters of each of the media, increased the amount of growth and also the effectiveness of the inoculation. The addition of 3 cubic centimeters of the normal solution of NaOH reduced the amount of growth and the infecting power. The heaviest growth took place on medium 337 to which the above amounts of NaOH were added, but the plants inoculated with these cultures did not produce as many nodules as did the plants inoculated with the organisms propagated on media 334 and 335 — a fact that suggests the possibility of a reduction in infecting power.

The addition of cane sugar to medium 334 in the amounts indicated in table 8 has a beneficial influence on the multiplication of the organism. The infecting power does not seem to be affected by it. All the cultures in which any multiplication was observed produced positive inoculation, so that the infecting power of the organism was not destroyed. The variations in the number of nodules on the plants inoculated by the different cultures seem to indicate that the organisms propagated on medium 337 partly lost their infecting power. This measure of infecting power, however, is not accurate, and other explanations might easily be supplied. The most noticeable point was that positive inoculation was produced by all the cultures in which any multiplication took place, so that the growth and the infecting power seem to run parallel.

EXPERIMENT 12

INFLUENCE OF SOME OTHER MEDIA

The organism, isolated as described in Part I, was kept in the laboratory for two years on agar slopes, medium 335, before this experiment was started. During this time the organism was continually exposed to diffused light and to the ordinary variations in temperature and humidity. The organism was then propagated on agar slopes, medium 334, to which various substances were added as is indicated in tables 9 and 10. Twelve

TABLE 9. DESCRIPTION OF THREE-WEEKS-OLD GROWTH OF B. RADICICOLA ON AGAR SLOPES

Medium 334 with	Description of growth
2.0 per cent cane sugar	Good, watery
2.0 per cent dextrose	Good, watery
2.0 per cent levulose	Not visible
2.0 per cent lactose	Not so good as with cane sugar
2.0 per cent galactose	Good, watery
10.0 per cent cane sugar	Good, watery
20.0 per cent cane sugar	Good, watery
40.0 per cent cane sugar	Slight, very transparent
2.0 per cent glycerin	Good, watery
2.0 per cent mannite	Good, watery
0.1 per cent asparagin	Fair
1.0 per cent salicin	Fair, whitish, not watery
0.5 per cent amygdalin	Fair, whitish
0.5 per cent resorcin	Hardly visible
0.2 per cent phloroglucin	Not visible
0.5 per cent potassium oxalate	Not visible
0.5 per cent potassium citrate	Not visible
0.1 per cent potassium nitrate	Poor, fluorescent, opaque
0.2 per cent potassium nitrate	Poor, fluorescent, opaque
0.6 per cent potassium nitrate	Poor, fluorescent, opaque
0.1 per cent calcium nitrate	Medium, very opaque, fluorescent, tough, brownish
0.2 per cent calcium nitrate	Medium, very opaque, fluorescent, tough, brownish
0.6 per cent ca cium nitrate	Medium, very opaque, fluorescent, tough, brownish
1.0 per cent gelatin	Medium, juicy, opaque
5.0 per cent gelatin	Poor
1.0 per cent Witte's peptone	Abundant, juicy
2.0 per cent Witte's peptone	Abundant, juicy
5 0 per cent Witte's peptone	Not visible
0.2 per cent Merck's peptone	Abundant, fluorescent, whitish to brownish
1.0 per cent Merck's peptone	Abundant, fluorescent, whitish to brownish
3 0 per cent Merck's peptone	Not visible

tubes of each medium were prepared, and after being sterilized they were sloped and inoculated.

The following substances were used alone as media: soy bean hay, ground; soy bean roots, ground; Canada field pea hay, ground; Canada field pea roots, ground; Canada field pea seeds, ground; compost (well-decomposed cow feces), ground; partly decomposed cow feces, ground; fresh cow feces, ground; corn meal; sawdust; wheat bran; wheat middlings; sandy soil; muck; cornstarch. These substances were dried at 100° C.,

ground fine, and then introduced into test tubes 25 x 180 millimeters in size. Each tube was filled to one-third its capacity. Twelve test tubes were prepared for each medium, plugged with cotton, and sterilized in the autoclave for one hour at 15° C. For inoculation 10 cubic centimeters of sterile water in which the organisms were suspended was added to each test tube. At the end of two weeks the test tubes were sealed with paraffin in order to reduce evaporation. All the cultures were kept in the laboratory at room temperature.

Three tests were made in order to determine the infecting power of the organism propagated on the various media. The first test was made at the end of the third week, the second at the end of the tenth week, and the third at the end of the twentieth week. In these tests one test tube was taken from each of the media, the total number of organisms in each of these tubes was determined by the plate method, and Canada field pea plants were inoculated.

The plants were grown in sterilized sandy soil in flowerpots, three flowerpots being inoculated with each culture. When the plants were three weeks old they were examined and the nodules on each plant were counted. In table 9 is given a description of the three-weeks-old growth

TABLE 10. NUMBER OF ORGANISMS IN THE VARIOUS MEDIA AT THE TIME THE TESTS WERE MADE

Medium	Number of organisms per gram		
	Cultures three weeks old	Cultures ten weeks old	Cultures twenty weeks old
Soy bean hay	0	0	0
Soy bean roots	0	0	0
Canada field pea hay	Few	0	0
Canada field pea roots	1,500,000,000	306,000,000	0
Canada field pea seeds	10,000,000,000	185,000,000	....
Compost	340,000,000	75,000,000	120,000,000
Partly decomposed cow feces	120,000,000	75,000,000	3,240,000,000
Fresh cow feces	60,000,000	440,000,000	810,000,000
Corn meal	7,200,000,000	Contamination	97,000,000
Sawdust	32,000,000	3,000,000	3,500,000
Wheat bran	10,000,000,000	370,000,000	600,000,000
Wheat middlings	4,000,000,000	390,000,000	420,000,000
Sandy soil	60,000,000	37,000,000	20,000,000
Muck	620,000,000	222,000,000	240,000,000
Cornstarch	200,000,000	55,000,000	97,000,000

TABLE 10 (*concluded*)

Medium 334 with	Number of organisms on one agar slope		
	Cultures three weeks old	Cultures ten weeks old	Cultures twenty weeks old
2.0 per cent cane sugar	No count made	300,000,000	90,000,000
10.0 per cent cane sugar	No count made	3,000,000	5,000,000
20.0 per cent cane sugar	No count made	1,000,000	10,000
40.0 per cent cane sugar	No count made	16,000,000	No colonies
2.0 per cent dextrose	No count made	31,000,000	52,000,000
2.0 per cent levulose	No count made	400,000	No colonies
2.0 per cent lactose	No count made	Plates spoiled	180,000
2.0 per cent galactose	No count made	3,000,000	600,000
2.0 per cent glycerin	No count made	250,000,000	20,000,000
2.0 per cent mannite	No count made	....	25,000,000
0.1 per cent asparagin	No count made	300,000,000	108,000,000
1.0 per cent salicin	No count made	No colonies	No colonies
0.5 per cent amygdalin	No count made	250,000,000	No colonies
0.5 per cent resorcin	No count made	No colonies	No colonies
0.2 per cent phloroglucin	No count made	Few	No colonies
0.1 per cent potassium nitrate	No count made	120,000,000	72,000,000
0.2 per cent potassium nitrate	No count made	74,000,000	224,000,000
0.6 per cent potassium nitrate	No count made	259,000,000	144,000,000
0.1 per cent calcium nitrate	No count made	280,000,000	486,000,000
0.2 per cent calcium nitrate	No count made	150,000,000	108,000,000
0.6 per cent calcium nitrate	No count made	400,000,000	130,000,000
1.0 per cent gelatin	No count made	150,000,000	64,000,000
5.0 per cent gelatin	No count made	50,000,000	Plates spoiled
1.0 per cent Witte's peptone	No count made	50,000	216,000,000
2.0 per cent Witte's peptone	No count made	Contaminated	648,000,000
5.0 per cent Witte's peptone	No count made	No colonies	No colonies
0.2 per cent Merck's peptone	No count made	22,000,000	8,000,000
1.0 per cent Merck's peptone	No count made	300,000,000	324,000,000
3.0 per cent Merck's peptone	No count made	No colonies	No colonies
0.5 per cent potassium oxalate	No count made	No colonies	No colonies
0.5 per cent potassium citrate	No count made	No colonies	No colonies

of *B. radicicola* on the agar slopes to which the various chemicals were added. The number of organisms in the cultures on the various media at the time they were tested for their efficiency to produce nodules is given in table 10. The results of the inoculations are shown in tables 11, 12, and 13.

Results

Growth and number of organisms (tables 9 and 10)

Bacillus radicicola of Canada field pea produces scant growth on agar

slope medium 334. Some of the substances that were added to this medium retarded or completely inhibited the growth; others had no appreciable effect on the growth; and still others caused a decided increase in the growth as compared with that on medium 334 alone. (Table 9.) No visible growth was produced when the following substances were added: levulose 2 per cent, phloroglucin 0.2 per cent, potassium oxalate 0.5 per cent, potassium citrate 0.5 per cent, Witte's peptone 5 per cent, Merck's peptone 3 per cent. The growth in the remaining cultures was watery, almost transparent, very viscous, especially in the presence of sugars.

The number of organisms on the agar slopes was determined when the cultures were ten and twenty weeks old, and in the case of the substances in which the organism was propagated the determination was made at three, ten, and twenty weeks. The data in table 10 show a wide variation; but in general, wherever a visible amount of growth appeared on the agar slopes large numbers of organisms were found. At the end of ten weeks no organisms were found in the presence of salicin 1 per cent, resorcin 0.5 per cent, Witte's peptone 5 per cent, Merck's peptone 3 per cent, potassium oxalate 0.5 per cent, and potassium citrate 0.5 per cent. At the end of twenty weeks, in addition to the above no organisms were found in the presence of cane sugar 40 per cent, levulose 2 per cent, amygdalin 0.5 per cent, and phloroglucin 0.2 per cent.

Very large numbers of the organism were found on most of the substances that were ground and used as media. Wheat bran and ground Canada field pea seeds each had 10,000,000,000 organisms per gram at the end of three weeks. The organisms remained in a vigorous condition on these media for twenty weeks, as judged by the development of colonies and by the results of inoculation of the plants. In soy bean hay and soy bean roots no multiplication took place, and the organisms introduced at the time of seeding these two media were found to be dead at the end of three weeks.

First test of infecting power (table 11)

Three flowerpots were inoculated with each culture, these cultures being three weeks old when used. The inoculated plants were kept in the greenhouse and were examined for nodule development three weeks after inoculation. The data are presented in table 11:

TABLE 11. INFECTING POWER OF CULTURES THREE WEEKS OLD

Medium 334 with	Nodules in flower-pot 1	Nodules in flower-pot 2	Nodules in flower-pot 3
2.0 per cent cane sugar	Many	Many	Many
2.0 per cent dextrose	Many	Many	Few
2.0 per cent levulose	None	None	None
2.0 per cent lactose	Many	Many	Many
2.0 per cent galactose	Many	Many	Many
10.0 per cent cane sugar	Many	Many	Few
20.0 per cent cane sugar	Few	Few	Few
30.0 per cent cane sugar	Few	Few	Many
40.0 per cent cane sugar	Few	Few	Few
1.0 per cent salicin	Many	Many	None
0.5 per cent amygdalin	Many	Few	Few
0.5 per cent resorcin	None	None	Few
0.2 per cent phloroglucin	Few	Few	Few
0.5 per cent potassium oxalate	None	None	None
0.5 per cent potassium citrate	None	None	None
0.1 per cent potassium nitrate	Many	Many	Many
0.2 per cent potassium nitrate	Many	Many	Few
0.6 per cent potassium nitrate	Few	Few	Few
0.1 per cent calcium nitrate	Many	Many	Few
0.2 per cent calcium nitrate	Many	Many	Few
0.6 per cent calcium nitrate	Many	Many	Many
1.0 per cent Witte's peptone	Many	Many	Many
2.0 per cent Witte's peptone	Few	Few	None
5.0 per cent Witte's peptone	None	None	None
0.2 per cent Merck's peptone	Many	Many	Many
1.0 per cent Merck's peptone	Many	Many	Many
3.0 per cent Merck's peptone	None	None	None
Other media			
Soy bean hay	None	None	None
Soy bean roots	Few	Few	Few
Canada field pea hay	Few	Few	Few
Canada field pea roots	Many	Many	Many
Sandy soil	Many	Many	Many
Muck	Many	Many	Many
Sawdust	Many	Many	Many
Wheat bran	Many	Many	Many
Wheat middlings	Many	Many	Many
Corn meal	Many	Many	Many
Ground field peas	Many	Many	Many
Compost	Many	Many	Many
Partly decomposed cow feces	Many	Many	Many
Fresh cow feces	Many	Many	Many
Controls	None	None	None
Controls	None	None	None
Controls	None	None	None
Controls	None	None	None
Controls	None	None	None

As far as could be ascertained by these results, there was no reduction in the infecting power of the organisms when they were propagated and kept on the above media for three weeks. When these results are compared with the data in tables 9 and 10, it is seen that those cultures in which no visible growth took place produced either no inoculation or very poor inoculation, and that the cultures in which the organisms multiplied produced good inoculation.

Second test of infecting power (table 12)

In this test the cultures were ten weeks old. The exact number of nodules on each plant was counted, and from these figures calculations were made of (1) the total number of nodules in each flowerpot, (2) the average number of nodules per plant in each flowerpot, and (3) the average number of nodules per plant of all the plants inoculated with the same culture. It was hoped that the averages would give a more nearly accurate measure of the infecting power of the different cultures. The data are given in table 12. Fifteen plants were inoculated with each culture, five plants being grown in each flowerpot.

TABLE 12. INFECTING POWER OF CULTURES TEN WEEKS OLD

Laboratory number of culture	Medium in which *B. radicicola* was propagated	Laboratory number of flowerpots	Number of nodules on each plant					Total number of nodules in each flowerpot	Average number of nodules per plant in each flowerpot	Average number of nodules per plant produced by the culture
			Plant 1	Plant 2	Plant 3	Plant 4	Plant 5			
1	Medium 334 + 2 per cent cane sugar	1	14	4	1	0	12	31	6.2	
		2	22	10	2	9	12	55	11.0	8.6
		3	....	....	....	....	....	......	......	
2	Medium 334 + 2 per cent cane sugar	4	6	0	3	10	4	23	4.6	
		5	12	4	15	12	10	53	10.6	7.5
		6	14	7	6	2	7	36	7.2	
4	Medium 334 + 10 per cent cane sugar	7	5	7	14	12	12	50	10.0	
		8	10	8	14	8	....	40	10.0	10.2
		9	10	15	18	5	5	53	10.6	

TABLE 12 (*continued*)

Laboratory number of culture	Medium in which *B. radicicola* was propagated	Laboratory number of flowerpots	Number of nodules on each plant: Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Total number of nodules in each flowerpot	Average number of nodules per plant in each flowerpot	Average number of nodules per plant produced by the culture
6	Medium 334 + 20 per cent cane sugar	10	8	1	8	2	3	22	4.4	
		11	15	5	1	0	5	26	5.2	3.7
		12	4	0	4	0	0	8	1.6	
7	Medium 334 + 40 per cent cane sugar	13	11	8	9	5	....	33	8.2	
		14	18	12	8	16	....	54	13.5	9.2
		15	8	3	8	8	6	33	6.6	
8	Medium 334 + 2 per cent dextrose	16	0	14	15	10	9	48	9.6	
		17	10	12	14	7	....	43	10.7	8.7
		18	4	8	4	6	....	22	5.5	
9	Medium 334 + 2 per cent lactose	19	0	3	1	5	....	9	2.2	
		20	3	1	0	2	3	9	1.8	2.1
		21	0	6	5	0	0	11	2.2	
10	Medium 334 + 2 per cent galactose	22	5	8	7	....	....	20	6.7	
		23	10	11	16	4	....	41	10.2	9.7
		24	8	9	10	15	14	56	11.2	
12	Medium 334 + 2 per cent glycerin	28	3	2	16	14	14	49	9.8	
		29	15	15	20	10	....	60	15.0	12.1
		30	....	....	....	....	....	......	......	
13	Medium 334 + 0.5 per cent potassium oxalate	31	0	0	0	0	0	0	0	
		32	0	2	3	4	....	9	2.2	0.6
		33	0	0	0	0	0	0	0	
14	Medium 334 + 0.2 per cent phloroglucin	34	0	0	0	3	....	3	0.7	
		35	0	0	0	0	....	0	0	2.2
		36	1	3	2	5	15	26	5.2	
15	Medium 334 + 0.5 per cent resorcin	37	5	5	5	8	....	23	5.7	
		38	1	4	0	6	....	11	2.7	2.6
		39	0	0	0	0	0	0	0	
16	Medium 334 + 1 per cent salicin	40	0	2	4	0	3	9	1.8	
		41	10	0	0	5	12	27	5.4	3.0
		42	0	2	0	4	....	6	1.5	
17	Medium 334 + 0.5 per cent amygdalin	43	0	8	14	2	16	40	8.0	
		44	10	15	24	15	8	72	14.4	12.0
		45	14	20	10	....	....	44	14.7	

TABLE 12 (*continued*)

Laboratory number of culture	Medium in which *B. radicicola* was propagated	Laboratory number of flowerpots	Number of nodules on each plant: Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Total number of nodules in each flowerpot	Average number of nodules per plant in each flowerpot	Average number of nodules per plant produced by the culture
18	Medium 334 + 0.1 per cent asparagin	46	16	10	6	18	10	60	12.0	8.8
		47	10	5	8	10	....	33	8.2	
		48	6	0	12	2	10	30	6.0	
19	Medium 334 + 0.1 per cent potassium nitrate	49	7	3	10	12	15	47	9.4	6.9
		50	12	5	6	0	0	23	4.6	
		51	13	15	0	0	5	33	6.6	
20	Medium 334 + 0.2 per cent potassium nitrate	52	2	2	6	9	10	29	5.8	5.3
		53	1	8	8	12	1	30	6.0	
		54	0	2	1	8	10	21	4.2	
21	Medium 334 + 0.6 per cent potassium nitrate	55	10	16	10	18	2	56	11.2	10.6
		56	13	16	2	30	....	61	15.2	
		57	12	0	5	2	12	31	6.2	
22	Medium 334 + 0.1 per cent calcium nitrate	58	3	2	5	10	8	28	5.6	6.7
		59	6	6	3	10	8	33	6.6	
		60	8	0	14	5	12	39	7.8	
23	Medium 334 + 0.2 per cent calcium nitrate	61	12	12	10	5	14	53	10.6	13.1
		62	6	6	20	18	22	72	14.4	
		63	16	12	20	8	16	72	14.4	
24	Medium 334 + 0.6 per cent calcium nitrate	64	12	4	3	0	10	29	5.8	5.2
		65	3	2	7	7	9	28	5.6	
		66	0	0	6	10	5	21	4.2	
25	Medium 334 + 0.5 per cent potassium citrate	67	4	2	3	1	....	10	2.5	0.7
		68	0	0	0	0	0	0	0	
		69	0	0	0	0	0	0	0	
26	Medium 334 + 0.2 per cent Merck's peptone	70	4	7	8	4	4	27	5.4	4.4
		71	0	2	5	5	....	12	3.0	
		72	0	0	5	7	10	22	4.4	
27	Medium 334 + 1 per cent Merck's peptone	73	0	2	8	7	14	31	6.2	6.3
		74	20	7	0	0	8	35	7.0	
		75	7	8	0	12	2	29	5.8	
28	Medium 334 + 1 per cent Witte's peptone	76	14	0	10	0	15	39	7.8	15.8
		77	14	35	20	30	....	99	24.7	
		78	5	30	25	7	....	67	16.7	

TABLE 12 (*continued*)

Laboratory number of culture	Medium in which *B. radicicola* was propagated	Laboratory number of flowerpots	Number of nodules on each plant: Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Total number of nodules in each flowerpot	Average number of nodules per plant in each flowerpot	Average number of nodules per plant produced by the culture
29	Medium 334 + 2 per cent Witte's peptone	79 80 81	0 2 0	2 3 1	0 4 5	4 0 0	0 1	6 10 6	1.2 2.0 1.5	1.6
30	Medium 334 + 5 per cent Witte's peptone	82 83 84	0 2 0	0 0 0	0 0 0	0 4 0	0 0 0	0 6 0	0 1.2 0	0.4
31	Medium 334 + 5 per cent gelatin	85 86 87	10 2 0	14 8 18	16 10 5	35 16 10	34 6 25	109 42 58	21.8 8.4 11.6	13.9
32	Soy bean roots, ground	88 89 90	0 0 2	0 0 0	0 1 0	3 7 0	0 0	3 8 2	0.6 2.0 0.4	0.9
33	Soy bean hay, ground	91 92 93	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0
34	Canada field pea roots, ground	94 95 96	0 8 3	0 10 20	5 6 5	8 12 8	6 10 4	19 46 40	3.8 9.2 8.0	7.0
35	Canada field pea hay, ground	97 98 99	12 0 0	5 0 0	2 7 0	8 2 0	.... 1 0	27 10 0	6.7 2.0 0	2.6
36	Sawdust	100 101 102	1 10 0	0 0 0	0 7 0	0 6 0	0 0 0	1 23 0	0.2 4.6 0	1.6
37	Corn meal	103 104 105	0 0 0	0 0 1	0 0 0	0 0 0	0 0 0	0 0 1	0 0 0.2	0.1
38	Cornstarch	106 107 108	2 18 7	6 6 15	0 2 8	12 12 15	16 20	36 38 65	7.2 9.5 13.0	9.9
39	Wheat bran	109 110 111	18 8	0 8	8 8	8 14	6 8	40 46	8.0 9.2	8.6

TABLE 12 (*concluded*)

Laboratory number of culture	Medium in which *B. radicicola* was propagated	Laboratory number of flowerpots	Number of nodules on each plant: Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Total number of nodules in each flowerpot	Average number of nodules per plant in each flowerpot	Average number of nodules per plant produced by the culture
40	Wheat middlings	112	6	18	20	4	10	58	11.6	9.8
		113	20	12	5	6	10	53	10.6	
		114	12	0	7	3	14	36	7.2	
41	Compost	115	16	3	0	0	....	19	4.7	8.4
		116	12	4	15	8	0	39	7.8	
		117	10	14	12	16	8	60	12.0	
42	Partly decomposed cow feces	118	5	6	7	5	10	33	6.6	7.4
		119	6	3	14	8	12	43	8.6	
		120	8	6	3	4	14	35	7.0	
43	Fresh cow feces	121	0	0	7	0	....	7	1.7	8.4
		122	3	7	20	5	12	47	9.4	
		123	20	10	12	12	10	64	12.8	
44	Muck	124	10	8	10	12	10	50	10.0	7.1
		125	6	6	5	9	0	26	5.2	
		126	3	12	8	3	5	31	6.2	
45	Sandy soil	127	22	14	16	0	5	57	11.4	8.5
		128	10	0	8	4	6	28	5.6	
		129	....	....	....	....	....	......	......	
46	Controls	130	0	0	0	0	0	0	0	0.2
		131	0	0	0	0	0	0	0	
		132	0	3	0	0	0	3	0.6	
47	Controls	133	0	0	0	....	....	0	0	0
		134	0	0	0	0	....	0	0	
		135	0	0	0	0	0	0	0	

The average numbers of nodules per plant for all the plants inoculated with each of the given cultures appear in the last column in table 12. In table 13 these numbers are rearranged in numerical order according to the average number of nodules per plant produced by each culture:

TABLE 13. AVERAGE NUMBER OF NODULES PER PLANT IN SECOND TEST, ARRANGED IN NUMERICAL ORDER

Medium	Organisms living or not living*	Number of nodules per plant
Medium 334 + 1 per cent Witte's peptone	+	15.8
Medium 334 + 5 per cent gelatin	+	13.9
Medium 334 + 0.2 per cent calcium nitrate	+	13.1
Medium 334 + 2 per cent glycerin	+	12.1
Medium 334 + 0.5 per cent amygdalin	+	12.0
Medium 334 + 0.6 per cent potassium nitrate	+	10.6
Medium 334 + 10 per cent cane sugar	+	10.2
Cornstarch	+	9.9
Wheat middlings	+	9.8
Medium 334 + 2 per cent galactose	+	9.7
Medium 334 + 40 per cent cane sugar	+	9.2
Medium 334 + 0.1 per cent asparagin	+	8.8
Medium 334 + 2 per cent dextrose	+	8.7
Medium 334 + 2 per cent cane sugar	+	8.6
Wheat bran	+	8.6
Sandy soil	+	8.5
Compost	+	8.4
Fresh cow feces	+	8.4
Medium 334 + 2 per cent cane sugar	+	7.5
Partly decomposed cow feces	+	7.4
Muck	+	7.1
Canada field pea roots	+	7.0
Medium 334 + 0.1 per cent potassium nitrate	+	6.9
Medium 334 + 0.1 per cent calcium nitrate	+	6.7
Medium 334 + 1 per cent Merck's peptone	+	6.3
Medium 334 + 0.2 per cent potassium nitrate	+	5.3
Medium 334 + 0.6 per cent calcium nitrate	+	5.2
Medium 334 + 0.2 per cent Merck's peptone	+	4.4
Medium 334 + 20 per cent cane sugar	+	3.7
Medium 334 + 1 per cent salicin	0	3.0
Medium 334 + 0.5 per cent resorcin	0	2.6
Canada field pea hay	0	2.6
Medium 334 + 0.2 per cent phloroglucin	0	2.2
Medium 334 + 2 per cent lactose	+	2.1
Sawdust	+	1.6
Medium 334 + 2 per cent Witte's peptone	0	1.6
Soy bean roots	0	0.9
Medium 334 + 0.5 per cent potassium citrate	0	0.7
Medium 334 + 0.5 per cent potassium oxalate	0	0.6
Medium 334 + 5 per cent Witte's peptone	0	0.4
Controls (not inoculated)	0	0.2
Corn meal (culture contaminated)	0	0.1
Controls (not inoculated)	0	0
Soy bean hay	0	0

* + indicates living organisms; 0 indicates no living organisms.

In making any deductions from the preceding data, it must be remembered that the plants in this and in the other experiments were grown under special conditions. If the number of nodules on the plants in this experiment were dependent only on the degree of infecting power of the organism, an excellent illustration of variation in the infecting power would here be shown. This variation would, in this case, be due to the nature of the medium in which the organism was propagated.

That the number of nodules on a plant may be influenced by other factors than the infecting power of the organism has been shown in Part II of this paper, and also by experiments of other investigators. But the part that such other factors have played in this second test must be only a conjecture.

In order that a nodule may be produced, it is necessary that at least one organism shall come in contact with the root, that it shall enter the tissue of the root, and that it shall multiply inside the tissue. At least six factors can be mentioned which may have been of some importance in this experiment in bringing about this result:

1. *The distribution of the organisms through the entire volume of the soil in each flowerpot.*—The plant roots grow rapidly during the first three weeks after planting, and unless the organisms are evenly distributed through the soil a variation in the number of nodules might result if the plants are not allowed to grow for more than three weeks. Watering would tend to bring about an even distribution. All the flowerpots were watered twice each week, but the amount of water introduced into each pot was not measured — although it was uniformly constant — and because of this the distribution of the organisms throughout the soil may not have been uniform in all the flowerpots during the first two weeks.

2. *The number of organisms introduced into the different flowerpots at the time of inoculation.*—There is no available evidence to show how important this factor may be. That it may have exercised some influence seems highly probable. Reference to table 10 shows that there was a very great difference in the total number of organisms in the various cultures, and consequently the flowerpots inoculated with these cultures did not receive the same number of organisms.

3. *Multiplication of the organisms in the soil after inoculation.*—*Bacillus radicicola* multiplies readily in the sterilized soil that was used for growing the plants. This does influence the total number and the distribution

of the organisms in the soil. Moreover, if the infecting power of the organism were easily affected by the medium, it would be easily affected by the soil into which the organisms were introduced at the time of inoculation. The result would be that in course of time the infecting power of the different organisms, although different at the beginning, would become the same for all the organisms. If this is true, the difficulty in measuring the infecting power of a given culture is very evident.

4. *Resistance of the plant against the invasion of the organism.*—Nothing is known of this in connection with the leguminous plants and the nodule-forming organism. If such a character does exist in the plants, it probably varies in the different individuals and would influence the number of nodules formed.

5. *Infection from other sources than the inoculating material.*

6. *Infecting power of the organisms.*

It is evident from the above discussion that the number of nodules on plants may be the result of several factors operating simultaneously, and that it would be a difficult matter to determine their influence singly. The number of nodules, therefore, is not an accurate measure of the infecting power of the different cultures. Unfortunately, however, no other measure is available. In interpreting the above data, therefore, the limitations in the accuracy of the method must be borne in mind.

Comparing the data in table 13 with those in table 10, a close relation may be observed between the condition of the cultures when ten weeks old and the number of nodules on the plants inoculated with these cultures. The following cultures had no living organisms:

Medium 334 + 2 per cent Witte's peptone
Medium 334 + 5 per cent Witte's peptone
Medium 334 + 0.5 per cent resorcin
Medium 334 + 1 per cent salicin
Medium 334 + 0.5 per cent potassium oxalate
Medium 334 + 0.5 per cent potassium citrate
Medium 334 + 0.2 per cent phloroglucin (few organisms)
Soy bean hay
Soy bean roots
Canada field pea hay
Corn meal

Reference to table 13 shows that the plants inoculated with these cultures produced three nodules or less per plant. Whether the few nodules found

resulted from contamination or from a few surviving organisms not detected by the plating can only be conjectured. The remaining cultures all produced good inoculation, with the exception of the sawdust and the lactose culture, the average number of nodules per plant varying between 3.7 and 15.8. To what extent this variation in the number of nodules is due to the infecting power of the different cultures it is difficult to say with certainty; but that a part of the variation is due to other causes is evident from the data in the next to the last column in table 12. In this column the figures represent the average number of nodules per plant for every flowerpot. Since three flowerpots were inoculated with each culture, the extent of variation in the number of nodules in these pots must be due to other causes than the infecting power. A number of the more pronounced cases of variation in the number of nodules in the three respective flowerpots which were inoculated by the same culture are shown in table 14:

TABLE 14. VARIATION IN AVERAGE NUMBER OF NODULES IN SOME OF THE FLOWERPOTS

Inoculated with culture number	Average number of nodules in		
	Flowerpot 1	Flowerpot 2	Flowerpot 3
28	24.7	7.8	16.7
31	21.8	8.4	11.6
21	15.2	6.2	11.2
17	14.7	8.0	14.4
7	13.5	6.6	8.2
38	13.0	7.2	9.5
43	12.8	1.7	9.4
18	12.0	6.0	8.2
41	12.0	4.7	7.8
45	11.4	5.6	....
1	11.0	6.2	....
8	10.7	5.5	9.6
2	10.6	4.6	7.2
44	10.0	5.2	6.2
34	9.2	3.8	8.0
6	5.2	1.6	4.4

The three flowerpots inoculated with culture 43 had 12.8, 1.7, and 9.4 nodules per plant, respectively. A similar relation exists between the other flowerpots considered in table 14. If the efficiency of these cultures were based on the number of nodules per plant, culture 43, for example,

would be either very efficient or much reduced in infecting power, depending on which flowerpot was taken.

It seems apparent, from the preceding discussion, that it is extremely difficult to measure any variations in the infecting power of different cultures. When the great danger of infection of plants grown in sterile soil but not under sterile conditions is considered, and also the number of other factors that may affect nodule development on plants, not many clear-cut conclusions can be drawn from the second test. If the infecting power is measured by the number of nodules, by their size, by the uniformity of their distribution, and by their location, the following conclusions seem reasonable:

1. The cultures producing more than three nodules per plant are all efficient.

2. If one culture produced 3.7 nodules per plant and another culture produced 15.8 nodules per plant, the belief that the latter culture possesses greater infecting power than the former is not justified.

3. Some cultures produced no nodules, or only a few nodules confined to only one or two plants. Such cultures unquestionably lost their efficiency, but this loss of efficiency was parallel with the condition of the cultures. When no living organisms were found in a culture by using the plate method, such a culture produced no inoculation; and when living organisms were found, inoculation was produced.

4. Propagating and keeping *B. radicicola* of Canada field pea for ten weeks on media rich in nitrogenous matter, such as wheat bran, wheat middlings, fresh cow feces, and potassium and calcium nitrates, did not destroy the infecting power of the organism. If any injury to infecting power was caused by these substances, it could not be detected by the methods used in this experiment.

Third test of infecting power (table 15)

Cultures twenty weeks old were employed in this experiment. In inoculating the plants a known number of organisms was introduced into each flowerpot. By correlating the relation between the number of organisms used for the inoculation of each flowerpot and the number of nodules on the plants, it was hoped to find a more nearly exact measure of the infecting power of the organisms propagated in the different media. The results are summarized in table 15:

TABLE 15. INFECTING POWER OF CULTURES TWENTY WEEKS OLD

Laboratory number of culture	Medium in which *B. radicicola* was propagated	Laboratory number of flower-pots	Number of nodules on each plant: Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Total number of nodules in each flowerpot	Average number of nodules per plant in each flowerpot	Average number of nodules per plant produced by the culture	Number of organisms introduced into each flowerpot
1	Medium 334 + 2 per cent cane sugar....	1	10	6	5	2	8	....	....	31	6.2	4.5	324,000
		2	4	2	0	0	4	....	....	10	2.0		324,000
		3	8	14	0	0	....	....	....	22	5.5		324,000
3	Medium 334 + 2 per cent cane sugar	4	10	14	6	0	....	....	....	30	7.5	4.8	259,200
		5	6	1	0	0	....	....	....	7	1.7		259,200
		6	8	6	0	6	5	....	....	25	5.0		259,200
4	Medium 334 + 10 per cent cane sugar....	7	0	0	0	0	0	....	....	......	......	3.1	90,000
		8	0	0	0	0	0	5	....	5	8.3		90,000
		9	0	0	0	0	0	....	....	......	......		90,000
5	Medium 334 + 10 per cent cane sugar	10	0	5	4	6	....	....	....	15	3.7	1.4	5,000
		11	0	0	0	0	0	....	....	0	0		5,000
		12	0	0	3	0	3	0	....	6	1.0		5,000
6	Medium 334 + 20 per cent cane sugar	13	0	0	0	0	0	....	....	0	0	3.0	10
		14	0	0	0	6	7	....	....	13	2.6		10
		15	6	12	8	....	....	....	....	26	8.7		10
7	Medium 334 + 40 per cent cane sugar	16	0	0	0	0	0	0	0	0	0	0	0
		17	0	0	0	0	....	....	....	0	0		0
		18	0	0	0	....	....	....	....	0	0		0
8	Medium 334 + 2 per cent dextrose	19	8	4	4	0	....	....	....	16	4.0	4.4	52,000
		20	0	6	6	8	....	....	....	20	5.0		52,000
		21	4	....	....	....	....	....	....	4	4.0		52.000
9	Medium 334 + 2 per cent lactose	22	5	4	12	6	8	0	....	35	5.8	5.3	180
		23	8	6	0	0	4	0	3	21	3.0		180
		24	8	0	16	10	....	....	....	34	8.5		180
10	Medium 334 + 2 per cent galactose	25	12	10	6	16	....	....	....	44	11.0	5.9	60,000
		26	5	4	15	6	0	5	8	43	6.1		600
		27	0	0	0	3	4	7	....	14	2.3		600
11	Medium 334 + 2 per cent mannite	28	10	1	0	10	14	7	....	42	7.0	7.6	250,000
		29	12	5	2	8	2	....	....	29	5.8		2,500
		30	16	8	12	....	....	....	....	36	12.0		2,500
12	Medium 334 + 2 per cent glycerin	31	12	15	6	7	5	10	3	58	8.3	10.5	2,000,000
		32	8	14	15	15	16	10	8	86	12.3		20,000
		33	8	9	7	11	18	14	....	67	11.2		20,000
13	Medium 334 + 0.5 per cent potassium oxalate	34	0	0	0	0	0	....	....	0	0	0.3	0
		35	0	0	0	0	0	0	....	0	0		0
		36	0	0	0	5	....	....	....	5	1.2		0
14	Medium 334 + 0.2 per cent phloroglucin	37	0	0	0	0	0	0	....	0	0	1.6	0
		38	0	0	4	8	6	....	....	18	3.6		0
		39	....	....	....	....	....	....	....	......	......		0
15	Medium 334 + 0.5 per cent resorcin	40	0	0	0	0	....	....	....	0	0	0	0
		41	0	0	0	0	0	....	....	0	0		0
		42	0	0	0	0	0	....	....	0	0		0
16	Medium 334 + 1 per cent salicin	43	0	0	0	0	0	0	....	0	0	0	0
		44	0	....	....	....	....	....	....	0	0		0
		45	0	0	0	....	....	....	....	0	0		0

TABLE 15 (continued)

Laboratory number of culture	Medium in which B. radicicola was propagated	Laboratory number of flowerpots	Number of nodules on each plant: Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Total number of nodules in each flowerpot	Average number of nodules per plant in each flowerpot	Average number of nodules per plant produced by the culture	Number of organisms introduced into each flowerpot
17	Medium 334 + 0.5 per cent amygdalin	46	0	0	0	0	....	....	....	0	0		0
		47	0	0	0	0	0	....	....	0	0	0	0
		48	0	0	0	....	....	....	....	0	0		0
18	Medium 334 + 0.1 per cent asparagin	49	5	16	17	18	7	0	....	63	10.5		10,800,000
		50	6	15	12	10	6	....	....	49	9.8	10.0	108,000
		51	8	0	16	12	18	4	....	58	9.7		108,000
19	Medium 334 + 0.1 per cent potassium nitrate	52	25	17	6	0	....	....	....	48	12.0		7,200,000
		53	0	8	10	0	26	....	....	44	8.8	9.5	72,000
		54	20	12	10	4	4	0	....	50	8.3		72,000
20	Medium 334 + 0.2 per cent potassium nitrate	55	3	5	3	10	5	3	....	29	4.8		224,000
		56	5	5	0	0	....	....	....	10	2.5	3.9	224,000
		57	....	....	....	....	....	....	....	......	......		224,000
21	Medium 334 + 0.6 per cent potassium nitrate	58	0	10	12	4	14	0	....	40	6.7		14,400,000
		59	14	3	12	....	....	....	....	29	9.7	6.7	144,000
		60	6	10	0	2	....	....	....	18	4.5		144,000
22	Medium 334 + 0.1 per cent calcium nitrate	61	12	12	8	2	6	....	....	40	8.0		48,600,000
		62	2	1	7	9	5	3	....	27	4.5	6.7	486,000
		63	8	4	16	0	5	14	....	47	7.8		486,000
23	Medium 334 + 0.2 per cent calcium nitrate	64	2	1	8	14	12	16	....	53	8.8		10,800,000
		65	20	8	5	6	16	18	6	79	11.3	8.6	108,000
		66	5	3	6	14	3	8	1	40	5.7		108,000
24	Medium 334 + 0.6 per cent calcium nitrate	67	6	10	8	11	....	....	....	35	8.7		13,000,000
		68	3	7	8	9	11	7	8	53	7.6	9.2	130,000
		69	13	8	10	16	12	....	....	59	11.8		130,000
25	Medium 334 + 0.5 per cent potassium citrate	70	12	12	16	4	6	....	....	50	10.0		300,000
		71	18	8	4	20	....	....	....	50	12.5	9.1	3,000
		72	1	0	8	12	7	....	....	28	5.6		3,000
26	Medium 334 + 0.2 per cent Merck's peptone	73	1	0	1	12	10	0	....	24	4.0		800,000
		74	3	5	12	12	....	....	....	32	8.0	5.9	8,000
		75	8	0	0	14	6	10	....	38	6.3		8,000
27	Medium 334 + 1 per cent Merck's peptone	76	2	4	10	14	....	....	....	30	7.5		32,400,000
		77	10	12	15	18	4	....	....	59	11.8	9.5	324,000
		78	12	13	0	....	....	....	....	25	8.3		324,000
28	Medium 334 + 1 per cent Witte's peptone	79	3	7	3	0	5	....	....	18	3.6		21,600,000
		80	4	12	10	12	14	15	20	87	12.4	9.4	216,000
		81	12	8	16	....	....	....	....	36	12.0		216,000
29	Medium 334 + 2 per cent Witte's peptone	82	12	4	4	10	....	....	....	30	7.5		64,800,000
		83	4	0	12	8	....	....	....	24	6.0	7.9	648,000
		84	10	14	9	....	....	....	....	33	11.0		648,000
30	Medium 334 + 5 per cent Witte's peptone	85	0	0	0	2	0	0	....	2	0.3		0
		86	0	0	0	0	0	0	....	0	0	0.1	0
		87	0	0	0	0	0	0	0	0	0		0
31	Medium 334 + 5 per cent gelatin	88	3	2	2	10	7	6	....	30	5.0		6,480,000
		89	5	8	7	6	8	2	....	36	6.0	6.6	64,800
		90	7	8	12	14	5	....	....	46	9.2		64,800

TABLE 15 (*concluded*)

Laboratory number of culture	Medium in which *B. radicicola* was propagated	Laboratory number of flowerpots	Number of nodules on each plant: Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Total number of nodules in each flowerpot	Average number of nodules per plant in each flowerpot	Average number of nodules per plant produced by the culture	Number of organisms introduced into each flowerpot
32	Soy bean roots, ground	91	0	0	0	0	....	....	....	0	0		0
		92	0	0	0	0	....	....	....	0	0	0	0
		93	0	0	0	0	0	0	....	0	0		0
33	Soy bean hay, ground	94	0	0	0	0	0	....	....	0	0		0
		95	0	0	0	0	....	....	....	0	0	0	0
		96	0	0	0	0	0	0	....	0	0		0
34	Canada field pea roots, ground	97	0	0	0	0	0	0	0	0	0		0
		98	0	0	0	0	....	....	....	0	0	0	0
		99	0	0	0	0	....	....	....	0	0		0
35	Canada field pea hay, ground	100	0	0	0	....	....	....	....	0	0		0
		101	0	0	0	0	....	....	....	0	0	0	0
		102	0	0	0	0	0	0	....	0	0		0
36	Sawdust............	103	15	....	....	....	....	....	....	15	15.0		350,000
		104	4	9	5	5	3	....	....	26	5.2	6.6	3,500
		105	5	....	....	....	....	....	....	5	5.0		3,500
37	Corn meal...........	106	6	10	8	16	....	....	....	40	10.0		9,700,000
		107	1	2	3	12	5	14	....	37	6.2	7.5	97,000
		108	12	6	8	8	1	....	....	35	7.0		97,000
38	Cornstarch..........	109	12	7	14	....	....	....	....	33	11.0		9,700,000
		110	5	6	....	....	....	....	....	11	5.5	9.1	97,000
		111	8	7	14	....	....	....	....	29	9.7		97,000
39	Wheat bran.........	112	7	12	10	....	....	....	....	29	9.7		60,000,000
		113	1	2	22	8	....	....	....	33	8.2	9.8	600,000
		114	14	22	0	....	....	....	....	36	12.0		600,000
40	Wheat middlings.....	115	20	10	2	10	....	....	....	42	10.5		42,000,000
		116	15	12	16	....	....	....	....	43	14.3	12.0	420,000
		117	12	10	13	....	....	....	....	35	11.7		420,000
41	Compost............	118	12	14	8	0	....	....	....	34	8.5		12,000,000
		119	8	2	6	....	....	....	....	16	5.3	7.3	120,000
		120	9	4	10	....	....	....	....	23	7.7		120,000
42	Partly decomposed cow feces	121	5	4	5	....	....	....	....	14	4.7		324,000,000
		122	6	12	7	3	16	20	....	64	10.7	8.3	3,240,000
		123	6	0	18	12	2	....	....	38	7.6		3,240,000
43	Fresh cow feces......	124	10	12	7	15	....	....	....	44	11.0		81,000,000
		125	14	0	5	12	....	....	....	31	7.7	9.4	810,000
		126	....	....	....	....	....	....	....	......	......		810,000
44	Muck...............	127	4	0	0	0	....	....	....	4	1.0		24,000,000
		128	8	12	0	0	....	....	....	20	5.0	3.5	240,000
		129	1	8	7	2	....	....	....	18	4.5		240,000
45	Sandy soil...........	130	21	10	7	6	....	....	....	44	11.0		2,000,000
		131	17	14	16	2	....	....	....	49	12.2	12.3	20,000
		132	12	22	8	....	....	....	....	42	14.0		20,000

In this test a known number of organisms was introduced into each flowerpot at the time of inoculation, in order to trace the relation between the number of nodules developed and the number of organisms used for inoculation. It was hoped that in this way some means might be found of measuring not only the loss, but also the degree, of infecting power. From the data in table 15 it is seen that absolutely no relation exists between the number of organisms introduced into the flowerpots and the number of nodules that developed, so that the only measure of infecting power is the presence or the absence of nodules. This, however, does not measure the degree of infecting power, but only its presence or absence.

The average number of nodules per plant produced by each culture, as shown in table 15, are rearranged in numerical order in table 16. It is found on comparing tables 13 and 16 that the results of the third test of infecting power show a general agreement with the results of the second test.

If it is considered that the presence of three or more nodules per plant indicates that the culture was efficient, the following cultures are seen to have lost their efficiency:

Soy bean hay
Soy bean roots
Canada field pea hay
Canada field pea roots
Medium 334 + 10 per cent cane sugar
Medium 334 + 40 per cent cane sugar
Medium 334 + 0.2 per cent phloroglucin
Medium 334 + 1 per cent salicin
Medium 334 + 0.5 per cent amygdalin
Medium 334 + 0.5 per cent resorcin
Medium 334 + 0.5 per cent potassium oxalate
Medium 334 + 5 per cent Witte's peptone

The cultures that had any living organisms at the time of inoculation produced nodules practically in all cases in the three tests. The cultures in which no living organisms were found produced no nodules, or only a few unevenly distributed. It must be remembered that a certain amount of contamination may occur, and that the method of determining the presence of living organisms by plate cultures is not absolutely accurate. The cultures in this test were ten weeks older than those in the second test. The results show that the nodule-bacteria cultures can be kept for at least twenty weeks, and the bacteria will still be efficient in producing nodules.

TABLE 16. AVERAGE NUMBER OF NODULES PER PLANT IN THIRD TEST, ARRANGED IN NUMERICAL ORDER

Medium	Organisms living or not living*	Number of nodules per plant
Sandy soil	+	12.3
Wheat middlings	+	12.0
Medium 334 + 2 per cent glycerin	+	10.5
Medium 334 + 0.1 per cent asparagin	+	10.0
Wheat bran	+	9.8
Medium 334 + 1 per cent Merck's peptone	+	9.5
Medium 334 + 0.1 per cent potassium nitrate	+	9.5
Medium 334 + 1 per cent Witte's peptone	+	9.4
Fresh cow feces	+	9.4
Medium 334 + 0.6 per cent calcium nitrate	+	9.2
Cornstarch	+	9.1
Medium 334 + 0.5 per cent potassium citrate	+	9.1
Medium 334 + 0.2 per cent calcium nitrate	+	8.6
Partly decomposed cow feces	+	8.3
Medium 334 + 2 per cent Witte's peptone	+	7.9
Medium 334 + 2 per cent mannite	+	7.6
Corn meal	+	7.5
Compost	+	7.3
Medium 334 + 0.1 per cent calcium nitrate	+	6.7
Medium 334 + 0.6 per cent potassium nitrate	+	6.7
Medium 334 + 5 per cent gelatin	+	6.6
Sawdust	+	6.6
Medium 334 + 2 per cent galactose	+	5.9
Medium 334 + 0.2 per cent Merck's peptone	+	5.9
Medium 334 + 2 per cent lactose	+	5.3
Medium 334 + 2 per cent cane sugar	+	4.8
Medium 334 + 2 per cent cane sugar	+	4.5
Medium 334 + 2 per cent dextrose	+	4.4
Medium 334 + 0.2 per cent potassium nitrate	+	3.9
Muck	+	3.5
Medium 334 + 10 per cent cane sugar	+	3.1
Medium 334 + 20 per cent cane sugar	+	3.0
Medium 334 + 0.2 per cent phloroglucin	0	1.6
Medium 334 + 10 per cent cane sugar	+	1.4
Medium 334 + 0.5 per cent potassium oxalate	0	0.3
Medium 334 + 5 per cent Witte's peptone	0	0.1
Medium 334 + 40 per cent cane sugar	0	0
Medium 334 + 0.5 per cent resorcin	0	0
Medium 334 + 1 per cent salicin	0	0
Medium 334 + 0.5 per cent amygdalin	0	0
Canada field pea hay	0	0
Canada field pea roots	0	0
Soy bean hay	0	0
Soy bean roots	0	0

* + indicates living organisms; 0 indicates no living organisms.

EXPERIMENT 13

INFLUENCE OF MEDIA 300, 310, 335, AND 400

The organism used for this experiment was propagated on medium 335, and had been kept in the laboratory for two years and three months, where it was exposed to diffused light and transfers had been made at intervals. When the experiment was started the organism readily produced nodules on the plants, showing that its infecting power had not been lost.

The plan of the experiment was to propagate the organism on both the nitrogen-free and the nitrogenous media for a period of time, and then to test these cultures for nodule production. The following procedure was adopted: Media 300, 310, 335, and 400 were introduced into test tubes, sterilized, and sloped. Four slopes from each of these media were inoculated with the same culture of the organism. A few days later a second set of four slopes from each medium was inoculated, and so on. Nine such sets of agar slopes from each of the four media were inoculated in one hundred and fifteen days. The four agar slopes of the same medium in each set were inoculated from one of the four slopes of the same medium from the previous set, so that on all the slopes of the same medium in the nine sets the organism was under the influence of the same media for one hundred and fifteen days. The age of the agar slopes, however, differed in the respective sets. When the ninth set was inoculated, four additional tubes of media 300, 310, and 400 were inoculated with a culture of the organism which up to that time had been propagated on nitrogen-free medium 335. These test-tube cultures are designated in table 17 as set X. They were fifteen days old and had been under the influence of nitrogenous media for only fifteen days when tested for infecting power. In order to prevent the effects of drying, melted paraffin was poured on the cotton plugs after a good growth had developed. All the cultures were kept at room temperature.

The infecting power of these agar-slope cultures was tested by inoculating Canada field peas. The method of growing and examining the plants was the same as in experiment 12. In inoculating the plants, the growth from each agar slope was introduced into 100 cubic centimeters of sterile water, the number of organisms in this was determined by the plate method, and a definite quantity of this infusion was poured over the seeds in each flowerpot.

Unfortunately, an accident happened to a large number of the flowerpots in the greenhouse, and consequently the data are not complete. As far as they could be obtained, they are summarized in table 17:

TABLE 17. INFLUENCE OF MEDIA 300, 310, 335, AND 400

Laboratory number of culture	Number of set	Medium	Age (in days) of culture when used for inoculation	Laboratory number of flowerpots	Number of nodules on each plant						Total number of nodules in each flowerpot	Average number of nodules per plant in each flowerpot	Average number of nodules per plant produced by the culture	Number of living organisms found in the culture
					Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6				
1	I	335	115	1	0	6	14	7	6	6	39	6.5	9.8	300,000,000
				2	13	15	12	7	8	....	55	11.0		
				3	25	16	2	....	....	....	43	14.3		
2	I	300	115	4	0	0	0	0	0	0	0	0	0	0
				5	0	0	0	0	....	....	0	0		
				6	0	0	0	....	....	....	0	0		
3	I	400	115	7	0	0	0	0	0	0	0	0	0	0
				8	0	0	0	0	0	0	0	0		
				9	0	0	0	0	0	0	0	0		
4	II	335	110	10	12	13	8	8	5	....	46	9.2	7.3	350,000,000
				11	6	8	8	5	5	2	34	5.7		
				12	....	....	....	....	....	....	....	....		
5	II	300	110	13	0	0	0	0	0	0	0	0	0	0
				14	0	0	0	0	0	0	0	0		
				15	0	0	0	0	....	....	0	0		
6	II	400	110	16	0	0	0	0	0	....	0	0	0.6	0
				17	0	0	0	0	0	4	4	0.7		
				18	0	0	0	0	6	....	6	1.2		
7	III	335	105	19	8	9	12	20	14	....	63	12.6	9.5	360,000,000
				20	9	20	6	7	4	....	46	9.2		
				21	8	10	7	8	0	....	33	6.6		
8	III	300	105	22	0	0	0	0	0	0	0	0	0	0
				23	0	0	0	0	0	0	0	0		
				24	0	0	0	0	0	0	0	0		
9	III	400	105	25	0	0	0	0	0	0	0	0	0	0
				26	0	0	0	0	0	0	0	0		
				27	0	0	0	0	0	0	0	0		
10	III	310	105	28	12	5	15	4	10	15	61	10.2	10.7	144,000,000
				29	14	16	6	18	8	13	75	12.5		
				30	7	10	6	12	....	....	35	8.7		
11	IV	400	98	31	0	2	0	0	....	....	2	0.5	0.5	90,000
				32	....	....	....	....	....	....	....	....		
				33	....	....	....	....	....	....	....	....		
12	VI	335	81	34	13	1	4	17	6	....	41	8.2	6.9	180,000,000
				35	4	2	14	8	2	5	35	5.8		
				36	14	10	6	0	8	3	41	6.8		
13	VI	300	81	37	0	0	0	0	0	0	0	0	0	0
				38	....	....	....	....	....	....	....	....		
				39	....	....	....	....	....	....	....	....		
14	VI	400	81	40	10	11	12	7	0	....	40	8.0	8.5	1,000,000
				41	0	20	6	7	13	8	54	9.0		
				42	12	10	6	6	....	....	34	8.5		
15	VI	310	81	43	20	15	8	0	....	....	43	10.7	10.7	540,000,000
				44	....	....	....	....	....	....	....	....		
				45	....	....	....	....	....	....	....	....		

TABLE 17 (*concluded*)

Laboratory number of culture	Number of set	Medium	Age (in days) of culture when used for inoculation	Laboratory number of flower-pots	Number of nodules on each plant: Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Total number of nodules in each flowerpot	Average number of nodules per plant in each flowerpot	Average number of nodules per plant produced by the culture	Number of living organisms found in the culture
16	VII	355	61	46	12	0	6	8	0	16	42	7.0	9.8	396,000,000
				47	16	7	15	6	20	....	64	12.8		
				48	3	20	0	6	22	9	60	10.0		
17	VII	400	61	49	2	10	4	....	....	....	16	5.3	7.7	10,000,000
				50	5	5	12	16	....	....	38	9.5		
				51	....	....	....	....	....	....	......	......		
18	VII	310	61	52	0	0	0	0	0	0	0	0	0	0
				53	0	0	0	0	0	0	0	0		
				54	0	0	0	0	0	0	0	0		
19	VIII	335	49	55	0	10	8	9	0	....	27	5.4	6.2	216,000,000
				56	8	5	0	....	....	....	13	4.3		
				57	8	10	9	7	....	....	34	8.5		
20	VIII	300	49	58	7	9	....	....	....	....	16	8.0	11.2	16,000,000
				59	6	7	18	7	16	12	66	11.0		
				60	6	13	30	4	....	....	53	13.2		
21	VIII	400	49	61	8	0	2	18	0	....	28	5.6	6.8	252,000,000
				62	12	13	4	4	14	....	47	9.4		
				63	4	0	1	6	16	....	27	5.4		
22	VIII	310	49	64	0	6	25	....	....	....	31	10.3	7.8	8,000,000
				65	6	10	6	5	....	....	27	6.7		
				66	12	2	0	10	12	....	36	7.2		
23	IX	335	15	67	10	6	5	2	8	....	31	6.2	4.5	576,000,000
				68	4	2	0	0	4	....	10	2.0		
				69	8	14	0	0	....	....	22	5.5		
24	IX	300	15	70	12	35	23	0	....	....	70	15.0	8.5	4,320,000,000
				71	18	0	0	13	5	8	44	7.3		
				72	0	7	0	2	5	....	14	2.8		
25	IX	400	15	73	0	5	8	0	....	....	13	3.2	5.8	2,592,000,000
				74	10	4	4	2	7	10	37	6.2		
				75	7	18	0	....	....	....	25	8.3		
26	IX	310	15	76	9	5	4	7	0	0	25	4.2	6.2	3,240,000,000
				77	8	0	4	7	....	....	19	4.7		
				78	12	8	8	15	0	12	55	9.2		
27	X	300	15	79	5	0	0	12	6	....	23	4.6	7.1	180,000,000
				80	4	7	30	20	12	....	73	14.6		
				81	0	0	3	3	5	....	11	2.2		
28	X	400	15	82	2	15	2	8	6	....	33	6.6	7.1	972,000,000
				83	5	9	1	6	6	8	35	5.8		
				84	6	8	0	25	6	8	53	8.8		
29	X	310	15	85	6	0	0	7	7	4	24	4.0	5.2	1,152,000,000
				86	0	0	0	0	7	10	17	2.8		
				87	12	25	0	....	....	....	37	12.3		

Results

The nature and the composition of the four media used in experiment 13 are given in table 1, page 11. No nitrogen in any form was added to medium 335. The other three media received 0.3 per cent of Liebig's beef extract, and, in addition to this, media 300 and 310 received 1 per cent and medium 400 received 2 per cent of Witte's peptone. Medium 335 contained 2 per cent of cane sugar, and medium 310 contained 2 per cent of dextrose.

As seen from table 17, the age of the individual cultures varied between fifteen days and one hundred and fifteen days; but the organisms in all the cultures, except 27, 28, and 29, had been under the influence of their respective media for one hundred and fifteen days. Cultures 27, 28, and 29 were fifteen days old and had been under the influence of their respective media for only fifteen days, having been grown previously on medium 335.

The influence of these four media on the organism is shown in table 17. In order to bring out the relations more clearly, a part of these data are rearranged in table 18:

TABLE 18. INFLUENCE OF AGE OF CULTURES ON THE GIVEN MEDIA

Laboratory number of culture	Culture medium	Age of culture (days)	Average number of nodules per plant	Number of living organisms in culture
23	335	15	4.5	576,000,000
19	335	49	6.2	216,000,000
16	335	61	9.8	396,000,000
12	335	81	6.9	180,000,000
7	335	105	9.5	360,000,000
4	335	110	7.3	350,000,000
1	335	115	9.8	300,000,000
24	300	15	8.5	4,320,000,000
20	300	49	11.2	16,000,000
13	300	81	0	0
8	300	105	0	0
5	300	110	0	0
2	300	115	0	0
25	400	15	5.8	2,592,000,000
21	400	49	6.8	252,000,000
17	400	61	7.7	10,000,000
14	400	81	8.5	1,000,000

TABLE 18 (*concluded*)

Laboratory number of culture	Culture medium	Age of culture (days)	Average number of nodules per plant	Number of living organisms in culture
11	400	98	0.5	90,000
9	400	105	0	0
6	400	110	0.6	0
3	400	115	0	0
26	310	15	6.2	3,240,000,000
22	310	49	7.8	8,000,000
18	310	61	0	0
15	310	81	10.7	540,000,000
10	310	105	10.7	144,000,000
27	300	15	7.1	180,000,000
28	400	15	7.1	972,000,000
29	310	15	5.2	1,152,000,000

The organism had been propagated and kept on medium 335, a non-nitrogenous medium, for over two years before this experiment was started. Several tests of infecting power were made during that time. This medium was used also in experiment 12. As far as could be judged by all these tests, the infecting power of the organism remained constant when propagated and kept on this medium. Therefore the results shown in experiment 13 as to the infecting power of the cultures on medium 335 are taken to represent the normal infecting power of the organism, and serve as a basis for comparison of the infecting power of the cultures on the other media.

Of the seven cultures on medium 300, a nitrogenous medium, three cultures — namely, 20, 24, and 27 — produced nodules. Cultures 24 and 27 were fifteen days old and culture 20 was forty-nine days old. The organisms in cultures 20 and 24 were under the influence of medium 300 for one hundred and fifteen days, and culture 27 for only fifteen days. These three cultures appeared as effective as those on medium 335. The remaining cultures on medium 300 were from eighty-one to one hundred and fifteen days old and did not produce any nodules, apparently having lost their power of infection.

Similar results were obtained with the nitrogenous medium 400. Of

the nine cultures on this medium, five produced nodules, two were doubtful, and two produced no nodules. Culture 28 was fifteen days old and had been under the influence of this medium for only fifteen days; while culture 25 was fifteen days old and had been under the influence of this medium for one hundred and fifteen days. No appreciable difference in the infecting power of these two cultures was observed.

Medium 310 is the same as medium 300 except that it contains 2 per cent of dextrose. Five of the six cultures on this medium produced nodules; one did not, and that was not the oldest culture. Comparing these results with those from medium 300, it seems as if the dextrose protected the infecting power of the organism on this medium.

In the last column of Table 18 the number of living organisms in each culture is given, and in the next to the last column the number of nodules per plant produced by each culture is given. It is seen that in all cases in which no living organisms were found in a culture no nodules were produced by that culture, and that the cultures in which living organisms were present produced nodules. Culture 6 is the only exception, but in this case only two plants out of sixteen had four and six nodules, respectively, and the size and location of these nodules pointed to later contamination.

According to the above data, *Bacillus radicicola* of Canada field pea does not lose its infecting power when propagated on medium 300 and 400 for one hundred and fifteen days. Some of the cultures on these two media did lose their infecting power, but in all cases these were the older cultures. This loss in efficiency is due to death of the culture, and death is induced by nitrogenous media after a considerable duration.

SUMMARY

1. The causal organism in the case of Canada field pea nodules is *Bacillus radicicola*. Its flagella are peritrichic, and eight was the largest number found. Its group number is B. 222.2322033.

2. Nodules developed both in light and in darkness. A larger number of nodules, however, developed in darkness.

3. Nodules developed readily both in the soil extract and in synthetic nutrient solutions in which the nitrates were either omitted or replaced by chlorides. The nodules continued to increase in number as long as the plants continued to grow.

4. In a full nutrient solution containing nitrates a few nodules may develop immediately after inoculation, but a subsequent continual development of nodules seems to be inhibited.

5. No nodule development took place in nutrient solutions in which the individual essential elements were omitted, except in the case of nitrogen.

6. In sandy soil a moisture content of 20 to 40 per cent was more favorable for nodule development than lower or higher percentages.

7. The addition of KNO_3, $Ca(NO_3)_2$, NH_4Cl, $FeCl_3$ KCl, or peptone to sandy soil in the proportion of $\frac{1}{4}$ gram of the salts to 300 grams of the soil, air-dry, had an inhibiting effect on nodule development on Canada field peas. The addition of $MgSO_4$, KH_2PO_4, $Ca(H_2PO_4)_2$, and tannic acid, especially at the lower concentrations, in 300 grams of the soil, had a beneficial effect on nodule development on Canada field peas.

8. Nutrition markedly influences the morphology of the nodule organisms.

9. The addition of 1 cubic centimeter or more of a normal solution of HCl to 10 cubic centimeters of agar medium 334, 335, or 337 was injurious to the vitality, and therefore to the infecting power, of the alfalfa-nodule organism. The addition of 2 cubic centimeters or less of a normal solution of NaOH to 10 cubic centimeters of each of the above media seemed to be slightly beneficial to the vitality and the infecting power of this organism.

10. The organism of Canada field peas produced no visible growth in medium 334 when the following substances were added: levulose 2 per cent, phloroglucin 0.2 per cent, potassium oxalate 0.5 per cent, potassium citrate 0.5 per cent, Witte's peptone 5 per cent, Merck's peptone 3 per cent.

11. The organism multiplies readily in some soils and in various substances; as many as 10,000,000,000 organisms per gram developed in wheat bran and in ground peas.

12. The infecting power of *B. radicicola* of Canada field pea was not affected after the organism had been kept on medium 335 for two years and a half in the laboratory, the culture being transferred once each month.

13. The infecting power of the organism was not appreciably influenced by the various media. All the cultures in which living nodule-forming organisms were found at the time of trial produced nodules.

14. In some media and under certain conditions the organisms died much sooner than in other media. The nitrogenous media did not seem to influence the infecting power of the organism.

15. It is not difficult to determine whether or not a given culture can produce nodules, but there is no accurate method of measuring the slight variations in infecting power that may exist in the different cultures.

GENERAL DISCUSSION

The definition of *virulence* as given by various authors in the medical texts is not clear, but in general the word is defined as meaning the power of microorganisms to invade and multiply in the tissues of a host and cause some injury or disease to the host. It was found by Peirce (1902), Fred (1911), and others, that the cells in the nodule are injured by the nodule-forming organism and become abnormal, and that for this reason the relation between the microorganism and the legume is a parasitic one. Furthermore, a nodule on a leguminous plant is a swelling, a hypertrophic formation; and morphologically speaking, it is an abnormality, or a form of disease. Nodule formation, therefore, may be considered as of a pathological nature. But, it may be asked, which is the normal root of the legume — the one with the nodules, or the one without the nodules, or both? Whatever the morphological and cytological evidence may be, one well-established fact stands out; namely, that leguminous plants are benefited by the presence of nodules. No positive evidence has been produced thus far to show that the microorganism which causes nodules is injurious to leguminous plants. The nodule-forming organism penetrates the root tissue, multiplies therein, and apparently derives its necessary food therefrom; and in return for this it enables the plant to obtain a certain amount of nitrogen. There is, therefore, a mutual and beneficial exchange and the relation is symbiotic.

The primary object of the experiments reported in this investigation was to determine whether the power of the nodule-forming organism to cause nodules is easily altered by artificial media. The nodule-forming organism of Canada field pea was chosen for this purpose, and the results apply only to that organism. It is probable that the organisms from other legumes might have given different results. Since the value of the investigation depended so much on the securing of a pure culture, the various precautions, as previously indicated, were adopted for this purpose.

The fact that a pure culture is obtained from a nodule and resembles in its cultural characteristics the true nodule-forming organism is not a sufficient proof that such an organism is the nodule-forming organism. De' Rossi (1907), in his investigation, emphasizes this point, and unquestionably the information on the general subject of nitrogen fixation by leguminous plants has been colored by results from experiments in which some organism other than the nodule-forming organism was employed.

As stated on page 59, the number, size, and location of the nodules on the roots are probably influenced by a number of factors. Since the number of nodules produced on the plants in a given time was used as the measure of the infecting power of the culture with which the plants were inoculated, it seemed advisable to study the influence of several factors and thus to determine whether Canada field peas readily form nodules under the conditions that it was planned to use in Part III. The results of these experiments in Part II tend to point to the conclusion that, in general, the conditions favoring the normal development of plants favor also the development of nodules. An exception to this is found in the fact that the presence of nitrates tends to inhibit the development of nodules, and at the same time favor the normal development of the plants. No satisfactory explanation for this phenomenon has as yet been given. The plants appear not to be injured by the presence of nitrates, and neither do the nodule-forming organisms seem to be injured when propagated on a medium in which nitrate is present (see experiment 13). The explanation that the plants are made more vigorous when supplied with nitrogen, and can more readily resist the invasion of the microorganisms, cannot be taken seriously. It might be noted here that the root system of Canada field peas grown in Pfeffer's nutrient solution appears normal, tending to become slightly brownish; but when the nitrate in the same solution is replaced by the chloride of the same metal, the root system becomes larger, the roots being more numerous and longer. Consequently, the rate of growth of the root tissue is accelerated by the absence of nitrates. Whether this somewhat rapid growth of the root tissue has any relation to nodule formation is not known. It is highly probable that a biological factor also influences the development of nodules. The microbial flora of the soil or of the solution in which the plants are grown is undoubtedly influenced by the composition of that soil or solution. The microorganisms that thrive best in a highly nitrogenous soil or solu-

tion, and the products of their metabolic activities, may exercise an injurious influence on the nodule organisms and thus prevent them from multiplication and distribution through the soil.

The influence of artificial media on the power of *Bacillus radicicola* to cause nodules is of considerable importance, in view of the fact that inoculation for leguminous crops with pure cultures is extensively practiced and the pure cultures have to be propagated on some media. Frank (1899), in commenting on the low efficiency of nitragin, suggested that probably the medium (gelatin) on which the cultures were propagated and kept was not favorable for the organisms, and that this might be the cause of the low efficiency of nitragin. Hiltner (1900) finally substituted liquid media for the gelatin, and was able to obtain better results from the legume inoculation. Süchting (1904) found that not only the gelatin media are injurious to the bacteria — a point shown by Hiltner — but the agar media also may be unfavorable. Moore (1905) made the observation that the nodule-forming bacteria increase most rapidly on a medium rich in nitrogen, but that the resulting growth is usually very much reduced in infecting power. Lewis and Nicholson (1905), on the other hand, state that the presence or absence of nitrogen in the culture media is not the determining factor in maintaining the activity of the germ.

A reasonable conclusion from the investigations mentioned above seems to be that some artificial media are more favorable than others for the propagation of *B. radicicola*, and that the amount of growth is not always directly proportional to the nodule-producing efficiency of the organism. With this conclusion the experiments in Part III are in accord. In addition to this, the experiments point to the conclusion that *B. radicicola* of Canada field pea does not possess "virulence" in a pathological meaning of the word. The ability to cause nodules is so closely bound up with the general vitality of the bacteria that our means and methods cannot detect any variations, if such there are, in their nodule-producing ability. The writer's opinion is that every living nodule-producing organism in a vigorous condition, will, if given a chance, cause nodule development no matter on what kind of media it has been propagated. The propagation of the organisms on different media does not measurably affect their nodule-producing efficiency. The organisms die sooner on some media than on others, and the loss of the nodule-

producing efficiency of the cultures is due to the dying-out of the organisms. Whether the injurious agent is some ingredient of the media, or lack of a proper nutrient, or the accumulation of the metabolic products, has not been determined. The observation that a cop ous growth is usually of reduced nodule-producing efficiency suggests the last as the probable, or at least a partial, explanation.

When one examines leguminous plants grown under favorable conditions, one finds that each plant has a limited number of nodules and that the number and the size of the nodules vary on the different plants. Hiltner (1900), holding the relation between *B. radicicola* and the leguminous plants to be of a pathological nature, concluded from his experiments that the variableness of the infecting power of the nodule-forming bacteria is the limiting factor which determines the number and size of the nodules under otherwise favorable conditions. Süchting (1904), in trying to account for the limited number of nodules on each plant, emphasized the resistance of the plants against the invasion of the bacteria. His explanation is as follows: " In contrast to Hiltner's immunity theory, I am of the opinion that the nodule formation and their number are regulated by the relation between the antibodies in the plant and the infecting substance of the bacteria." [7]

These explanations do not appear to the writer to explain the conditions. No pathological explanation can account for a limited number of nodules. The physical condition and the chemical composition of the soil, the amount of moisture, and the microbial flora of the soil, are some of the important factors that interfere, directly or indirectly, with the coming together of *B. radicicola* and the roots of the plants. The stage in the development of the plant, the rate of growth of the roots, the number of root hairs, the character of the root tissue, and other factors, may also play a part in limiting the development of nodules.

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[7] Translation from the original German.

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INDEX OF SECTIONS, GENERA, SPECIES, AND VARIETIES

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FUSARIA OF POTATOES

When the work was well under way and it became apparent that there are indeed a considerable number of species of Fusarium, it came to the writer's knowledge that the same thing was definitely proved, at least for European conditions, by Appel and Wollenweber (1910) in their *Grundlagen* (page 105), in which they state that most of the Fusaria described by them were isolated from the potato, mainly from the tubers. Since then this work has been continued with still greater confidence in its underlying principles, but now mainly in order to verify the European findings for the American conditions.[2]

All cultures of the Fusaria were obtained by isolations made from diseased parts of the potato plant, mainly from tubers received from pathologists in nearly every experiment station in the United States. Of all the strains of the Fusarium-like organisms thus obtained, over one hundred and twenty organisms at first seemed to differ in some way or another. After a careful comparative study of all these strains, more than half of the number proved to be identical with others.

Some of the remaining organisms were identified with several Fusaria described by Appel and Wollenweber (1910), by Jamieson and Wollenweber (1912), and by Wollenweber (1913, b and c). These are as follows:

Fusarium affine Faut. et Lamb.
F. coeruleum (Lib.) Sacc.
F. dimerum Penz.
F. discolor Ap. et Wr.
F. Martii Ap. et Wr.
F. metacroum Ap. et Wr.
F. oxysporum Schlecht., as described by Wollenweber
F. radicicola Wr.
F. Solani (Mart. p. par.) Ap. et Wr.
F. subulatum Ap. et Wr.
F. trichothecioides Wr.

Still other organisms were found to be very closely related either to some of the species named above or to certain other species, at the same time differing sufficiently from them to be separated on a con-

[2] The general discussion of the genus Fusarium was known to the writer before he began his work, when in the summer of 1911 Dr. Jensen received the *Grundlagen* and now and then read parts of it to the writer. Having no idea that Appel and Wollenweber were working mainly with the Fusaria of the potato, the writer did not study their work thoroughly as early as he should have.

servative basis from those species. These organisms were then designated as new varieties of the following old species:

Fusarium caudatum Wr. (one new variety)
F. culmorum (W. Smith) Sacc. (one new variety)
F. discolor Ap. et Wr. (one new variety)
F. falcatum Ap. et Wr. (one new variety)
F. Martii Ap. et Wr. (two new varieties)
F. metacroum Ap. et Wr. (one new variety)
F. oxysporum Schlecht. (three new varieties)
F. redolens Wr. (one new variety)
F. Solani (Mart. p. par.) Ap. et Wr. (two new varieties)
F. subulatum Ap. et Wr. (one new variety)
F. udum (Berk.) Wr. (one new variety)

The remaining organisms of the genus Fusarium were then named as new species and their varieties. It is probable that at least some of them have been previously described, but the descriptions given are so incomplete that any reasonable identification is doubtful. The matter of identification is discussed on another page.

Besides the Fusaria, several organisms were isolated in the course of the work which more or less closely resemble Fusarium though belonging to a different genus (Ramularia) of the Hyphomycetes. As these organisms are often found on the potato and are easily confused with species of Fusarium, they are treated here, but of course under their proper generic name.

On the whole the work, with a few exceptions, fully verifies the principles laid down by Appel and Wollenweber (1910). The chief exceptions are as follows: (1) The Fusaria as such can be distinguished on almost any medium, including artificial media, provided that the medium is not extremely poor or rich in food materials and also provided that the moisture supply in the medium is well regulated. (2) The microconidia should be recognized as a special kind of spores because of their importance in classification of these fungi. Though microconidia genetically do not represent a separate kind of spores, nevertheless their typical absence for certain closely related Fusaria, as well as their typical presence for others, is characteristic. Besides, whenever they are present they have a constant and often distinctive type of their own. (3) No typical core-

mial nor typical pionnotal form of fructification was observed in any of the true Fusaria, though types of fructification resembling those forms more or less closely were common.

SCOPE OF WORK

The work was confined to a study of the Fusaria as such, that is, without any consideration of the possible perfect forms.[3] The study was centered mainly on the characters that seem to be most important and practicable for a natural classification of these organisms. Thus, especial attention was paid to the presence and type of each kind of spores (micro- and macroconidia and chlamydospores). Type of color production was found to be next in importance. Type of fructification and of conidiophores, size of spores, presence or absence and kind of sclerotia, and rate and character of colony growth, were also found to be of more or less considerable importance for differentiation of the species.

Some work has been done on the action of these organisms under different environmental conditions and also with respect to their pathogenicity. In regard to the latter the following four facts should be mentioned:

1. Extensive inoculations of potato plants with all the Fusaria presented here yielded negative results and would indicate that they are not wilt producers.[4]

2. Several series of inoculations of potato tubers showed (a) that a considerable number of the Fusaria can cause more or less rapid decay of the tubers, and (b) that most of the Fusaria readily produce rot only after the tubers begin to sprout.

3. The commonest rot-producing organism, at least in eastern United States, is *F. coeruleum* (Lib.) Sacc.

4. The inoculations into tubers seem to indicate that some species widely different morphologically may act similarly pathologically, and that other species very closely related from the morphological standpoint differ very widely in their pathogenicity.

The other results of this phase of the work will be mentioned only in

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[3] In this study no special attempt was made to discover the perfect stage of any of these organisms. At the same time it is to be noted that under the condition of the work when a considerable number of "natural" as well as "artificial" media were used, none of the Fusaria produced a perfect stage.

[4] The writer does not mean by this statement that the Fusaria actually never produce wilt of potatoes, because it is possible that the negative results were due to lost virulence of the cultures used or to some other important factor that escaped attention.

those instances in which different action under different environment is of importance in identification.

SOURCE AND METHODS OF ISOLATION

Most of the species of Fusarium and related organisms presented here were isolated from potato tubers affected with dry or soft rot. A number of isolations were made also from discolored fibro-vascular bundles of potato tubers and from stems of wilted potato plants. A single organism, *Fusarium metacroum* var. *minus*, was isolated from a spot on the surface of a half-dead potato stem.

In a few cases the isolations were made by means of poured plate dilutions, but in the majority of cases they were made from affected tissues of the host. The affected part of the host was first thoroughly wiped with a piece of cheesecloth moistened in 0.1 per cent solution of corrosive sublimate, and then the "skin" was peeled off just above the affected part, or the diseased part of the plant was broken open so that the spot from which the isolation was to be made was not touched even with sterile utensils.[5] Four or five small fragments of diseased tissue were cut out with a sterile scalpel and transferred with a sterile needle to cooled poured plates of a suitable medium. When a rotted tuber showed a noticeable difference, in color or otherwise, in different regions of the decayed part, a separate set of plantings was made from each region. The actual isolation of more than one Fusarium from a single tuber shows that this precaution was, at least in some cases, worth while.

Several days after plantings were made, if any fungi were present they usually had made considerable growth and often allowed a preliminary macro- and microscopic comparison of the isolated organism with any others of the same series of isolations or of former ones.

In case a fungus thus obtained was different in some way[6] from the others, two transfers into test tubes of a suitable medium were made for further study. In order to make a culture from the start as pure as

[5] Small instruments and glassware may be sterilized conveniently by storing them in a jar of 80-per-cent alcohol. When ready to use the excess alcohol is burned off by passing the instruments through a flame. When so treated the instruments are sterile, perfectly dry, and not too hot for immediate use.

[6] Rate and character of growth, color, and type of spores were at first almost the only characters on which these organisms were judged.

possible, these transfers were made from the very margin of the colony. But if in a colony there were apparently two or more organisms growing together, this method would invariably lead to isolation of the rapidly growing one and loss of the slower-growing one. In order to save the latter also, the plates with original plantings were kept for a long time after the first transfers were made, and now and then dilutions were made from the old colonies. In the majority of cases this work was useless, but in two cases there were isolated very slow-growing fungi — *F. dimerum* var. *Solani* and *F. udum* var. *Solani* — which otherwise would have been missed.

The cultures obtained by transfers from original plantings seemed to be, and usually were, pure cultures from the start. Nevertheless it was evident that some method of obtaining cultures from single spores must be employed before a comparative study of the organism could be profitably begun.

In those few instances in which a culture did not produce any spores for a long time and which appeared to be a mixture of more than one fungus, an attempt was made to separate the organisms by the mere planting of a small bit of the fungous growth in the center of a newly poured plate. In only one case was the result satisfactory. This was when a bit of mixed growth of *F. arcuosporum* and *Ramularia Magnusiana*, on being planted in a plate, produced from the start on one side a pure growth of one fungus and on the other side a pure growth of the other fungus. In all the other cases a culture, if transferred into several different media, sooner or later always produced a sufficient number of spores; and in order to obtain a pure culture the poured-plate method of dilution was invariably employed.

Considerable economy of time and labor was effected by placing a number of separate drops of sterile water in a sterile plate. By transferring spores from drop to drop, a drop is soon secured in which the number of spores is such that a small loopful transferred to a drop in another plate will contain only thirty or forty spores. The melted and properly cooled medium is then poured into the plate, and distribution of spores is effected by giving the plate a rotary motion before the medium has hardened.

The first observation of the dilution plates was made about a day later. At this time most of the spores had germinated and could be observed

from the bottom of the plate with comparative ease. When a single spore at some distance from the others was located, it was marked with a circle of india ink. In this manner several spores were marked and the plate was left for another day, after which the colonies were usually large enough to be observed with the unaided eye. Transfers could then be made easily and surely. These transfers have been kept as the stock cultures. The dilution plates from which stock cultures were obtained were kept for several weeks longer, in order to see whether all the colonies were alike.

In only three cases, after the first dilution, did there appear to be different colonies present in the same separation plates. In one of these cases this was the result of a mixed growth of two distinct fungi. It is of some interest to note here that the mixed culture appeared to be a fine specimen of a pink fungus. On dilution it gave rise to a brick red fungus, *F. metacroum*, and a white one, *F. diversisporum*. In the other two cases the fungi obtained from the differently appearing colonies represented most closely related organisms which never were isolated again, but which nevertheless remain distinct from each other. Whether they represent mutations, fluctuations, or mere chance coexistence of the two actually different organisms, is a matter yet undecided. They are tentatively designated as two different varieties — *F. bullatum* var. *roseum* and *F. arthrosporioides* var. *asporotrichius*.

The stock cultures were subsequently repeatedly rediluted, and, as was to be expected, almost invariably[7] every dilution plate showed all the colonies from the same stock culture to be alike.

As it is not possible to use a high-power objective with the ordinary petri dish, and as single spores of some of the species are very difficult to locate because of their size and lack of color, there was always the possibility that some of the cultures which seemed to be pure were really mixtures, for it is a well-known fact that the spores of many fungi often cling together tenaciously. In order to make absolutely sure that pure cultures were being dealt with, the further precaution was observed in 1913 of locating single isolated spores with a high-power objective and

[7] Only two exceptions were observed: (1) In the case of *F. metacroum* var. *minus* among characteristic red colonies, there appeared one colorless colony. For a while the absence of color was a constant character, but later the color was produced again. (2) In the case of *F. diversisporum* among colonies with high aërial mycelium there was a colony almost without aërial mycelium. In subsequent generations the aërial mycelium reappeared almost to the same extent as originally.

securing cultures from them.[8] The cultures thus obtained were in all respects similar to the original stock cultures, thus confirming the reliability of the poured-plate dilution.

CULTURE MEDIA

It is a well-known fact among mycologists that under different environmental conditicns many fungi vary considerably in their macro- and microscopic characters. One of the most important factors in variability is the substratum. According to Thom (1910), certain characters in Penicillia appear only when the fungi are grown on a certain medium. Other instances of a similar nature might be cited.

Because of this variability of many fungi with variation in the substratum, it seemed indispensable in this study of Fusaria to use a number of different media in order to find the extent of the variability in the Fusaria and to determine, if possible, which media could be most profitably employed in this kind of work.

The so-called "natural" media, as well as artificial media, were used.[9] Those employed most extensively were potato tuber and stem plugs, and hard agars of potato, lima bean, and oat. For the study of color production, from 8 to 10 per cent of sugar (glucose) was added to one of the above agars, usually to potato agar. In all other cases the agars were used without glucose or with a small amount of it (0.5 per cent). In a few instances the agars were more or less acidified by the addition of small quantities of lactic or citric acid (from 1 to 3 drops of 50-per-cent acid

[8] The method employed was as follows: A number of drops (from eight to ten) of sterilized potato broth were placed on a sterile glass slide. Dilution transfers were made from drop to drop until such a dilution was secured that on removing a small droplet on the flattened end of a platinum needle it was found by microscopic examination that in many cases a single spore could be obtained. From such a drop nine transfers were made to a sterile, but somewhat greasy, cover glass. By placing the cover glass over a tubular glass cell or a van Tieghem cell, each individual droplet could be examined with a high-power objective. Droplets containing no spore or more than one spore were wiped off at once with a pointed piece of blotting paper. In thus removing spore droplets, the spores also were invariably removed. Sterile water was placed in the bottom of the cell and the cover glass was sealed to the cell with sterile water. The cells were then placed in a moist chamber for about twelve hours, and by this time the spores had usually germinated and could be observed with much greater ease. This observation was almost indispensable in the case of those species that produce numerous minute microconidia, as any such could be easily detected at this stage. Only two or three droplets bearing single unmistakably germinating spores were allowed to remain on the covers. At the end of twenty-four hours more, the growth of mycelium from the single spores was usually sufficient to be seen with the unaided eye and could be transferred readily with a finely pointed needle to a suitable medium.

[9] The media used were: (1) Natural — potato, bean, and pea stems; rye straw; canes of red raspberry; grains of rye, wheat, oat, barley, corn, and rice; corn meal and oatmeal; whole potato tubers and plugs of potato tuber. (2) Artificial — potato, lima-bean, oat, corn, and nutrient agars (hard and soft, from 1 to 3 per cent agar, neutral and more or less acidified, without and with different amounts of glucose).

to 10 cubic centimeters of the medium); otherwise they were used as they were after the process of cooking and sterilizing.[10]

The method of preparing all natural media was very simple. It consisted in cutting suitable pieces, tubing, and sterilizing in an autoclave for twenty minutes at fifteen pounds pressure. Enough distilled water was added to the tubes to keep the cultures in good growing condition for from three to four weeks, the exact amount, of course, depending on the size and succulence of the material used. The decoctions that were most commonly used were prepared in the following ways:

Potato decoction.— Two hundred grams of peeled potato tubers were sliced, 1000 cubic centimeters of distilled water was added, and the material was cooked for about forty minutes in a double boiler. The clear liquid was then decanted and the volume restored.

Lima-bean and oat decoctions were prepared by soaking 100 grams of ground lima beans or oats in 1000 cubic centimeters of distilled water at 60° C., in an incubator for an hour. The liquid was separated by straining through cheesecloth and the volume was restored to the original 1000 cubic centimeters.

Corn meal decoction was prepared as described by Shear and Wood (1913); that is, from about 35 to 40 grams of corn meal were treated in the same way as 100 grams of lima beans or oats in the preceding case.

For the artificial media, to 1000 cubic centimeters of a decoction were added agar (10, 15, or 30 grams, these amounts corresponding respectively to soft, medium, and hard agar) and glucose (0 to 100 grams), and the whole was cooked in a double boiler over a free flame for an hour, or, more exactly, until all the agar was well dissolved. The liquid was then tubed, plugged, and sterilized in the same way as were the natural media.

At the present stage of this work, it seems that all the labor spent on using so many different media was more or less wasted. It seems that the same results could as well be obtained with but a few good media, preferably the following: a hard oat agar (without glucose), a stem and tuber plug, and a potato agar with about 5 per cent of glucose. All other media used in the course of this work did not prove to be of any specific value, and at the best gave the same results that were obtained with those just named.

[10] When an acid was added to an agar this was done after the medium was sterilized, the medium then being quickly cooled. This quick cooling was necessary because otherwise an acidified agar often would not solidify as well as it should.

For determination of the color of the substratum and also for study of the colony growth, it would perhaps be best to use poured plates with about 10 cubic centimeters of a clear agar. In this work potato hard agar with from 5 to 10 per cent of glucose was almost exclusively used for this purpose. For the study of other characters, in most cases cultures were made in common test tubes.

EFFECT OF VARIOUS MEDIA ON DIFFERENT CHARACTERS OF FUSARIA

In the course of this work it was observed, in partial confirmation of the statement by Appel and Wollenweber (1910:12–23), that certain media affect fungous growth more or less characteristically. A medium too rich in nutrients, especially in glucose, usually gives cultures with more or less abnormal spores, the abnormality showing itself in a too dense granulation of the protoplasm, in more or less considerable swelling of the spore cells, and often in abnormal septation, size, and shape.

Media rich in glucose usually increase the density of color produced by these fungi, and often also change its character. For example, a pink fungus, *F. arcuosporum*, is turned to a clay-colored one; or the fungus *F. angustum*, which is colorless or nearly so, is turned to a more or less bright purplish-vinaceous one; and so forth.

Excess of water in a medium usually leads to comparatively quick degeneration (self-digestion?) of the spores, and, in general, to a shortened duration of the vitality of the culture. Its presence, at least in case of a soft agar as compared with a hard agar, is usually unfavorable for the normal development of aërial mycelium.

A medium comparatively poor in nutrients, such as corn meal agar, seldom gives rise to sclerotia and plectenchymic sporodochia; but in a way it is a good medium for the study of chlamydospores, which are produced here more or less freely and stand out more clearly than in other media.

Whole potato tubers (steamed) often are most favorable for production of large sporodochia; this medium, and also potato tuber plugs (also steamed), show the largest sclerotia.[11]

An agar, especially such a one as oat hard agar, often gives all the forms

[11] See also Wollenweber (1913 a: 25).

of fructification for these fungi, with "normal" spores and more or less typical and brilliant color production.[12]

On the plugs made from stems of different plants, spore production seems to be normal.[13] The spores are of typical and comparatively uniform shape, septation, and size, without too dense granulation of the protoplasm, and with a long duration of vitality. It often is found, however, that on such media spores are less normal than, for instance, on a hard agar.

Presence of the epidermis on the stem and tuber plugs seems to favor production of fewer but better developed sporodochia,[14] and often lessens development of aërial mycelium.

Certain media, such as boiled rice, give a color that is typical for certain related Fusaria.

EFFECT OF LIGHT AND OF REACTION OF THE MEDIUM ON DIFFERENT CHARACTERS OF FUSARIA

As was stated in the introduction, very little systematic work has been done on the ecology of the Fusaria. The few things which have been found by other workers and by the writer, and which have some value in the determination of these fungi, may be summed up briefly as follows:

1. A diffuse daylight may affect color production considerably (Smith and Swingle, 1904:48–49), but in most cases the effect is only slight or there is almost none. It usually intensifies the colors produced by these fungi. A very strong light often makes the colors somewhat duller, especially in the case of Fusaria producing bright red colors, these being turned toward brown hues. No noticeable effect of the light was observed on other characters of these fungi, although Appel and Wollenweber are of the opinion that the spores are of a more normal type in the light than in the dark.

2. According to Appel and Wollenweber the reaction of the medium has an especially noticeable effect on blue colors, which can appear only in a medium of neutral or rather alkaline reaction. The blue color in a medium of an acid reaction will appear as orange. True red colors remain

[12] This observation is apparently in some contradiction to the observations of Appel and Wollenweber (1910:12–13), but indeed it is not so; because, judging by the "artificial" media actually used by them, their observation of unfitness of such media for study of "normal" growth of the Fusaria was based on "soft" agars too rich in sugar. The writer also found that such agars produced abnormal growth.

[13] This was observed first by Appel and Wollenweber (1910), and on this observation mainly they concluded that the only way to study the Fusaria properly is to study them on such "natural" media.

[14] This was first observed by Appel and Wollenweber (1910).

red even in a medium of an alkaline reaction. The observations of the writer, so far as they go, are in full agreement with the above statements; to which it may be added that certain fungi which in a neutral medium produce a grayish white aërial mycelium (*F. sclerotioides*), in the same medium strongly acidified (0.4 per cent by weight of citric acid) produce an aërial mycelium of a pink-vinaceous shade.[15]

It was observed also that acidity of the medium lowers the rate of the fungous growth and makes zonation of the colony more prominent and closer. The retardation of the growth depends on the kind of acid (see also Smith and Swingle, 1904:42, 48) and its concentration; different Fusaria are not affected in the same degree, some tolerating more acid than others (see also Lewis, 1913:238).

THE GENUS FUSARIUM

Appel and Wollenweber (1910:4–12, 23–61) present a very detailed, critical study of the genus, with the following list of synonyms:

Atractium Link pr. p. (1809)
Fusidium Link pr. p. (1816 and 1825)
Fusisporium Link (1824)
Selenosporium Corda (1837)
Fusoma Corda (1837)
Pionnotes Fries (1849)

The description of the genus Fusarium given by these investigators, when other data presented by them are also taken into consideration and using the terminology of Lindau (1905, 1908–1909), may be stated in brief as follows:

Hyphomycetes of Mucedinaceæ-Hyalophragmiæ, Hyalostilbaceæ-Phragmosporæ, and Tuberculariaceæ-Mucedineæ-Phragmosporæ groups, with smooth, not appendiculate, mostly sickle-shaped, acrogenous, noncatenulate conidia.

The genus as delimited by these authors was to include also forms such as *F. dydimum* and *F. Willkommi*, with cylindrical, one-septate spores, and bacilliform, one- to five-septate spores.

The writer has not sufficient material on hand to warrant any change in the above characterization of the genus; but in the course of this work,

[15] The medium used in the instance cited was potato hard agar plus 5 per cent of glucose. The cultures were made in petri dishes.

a true Fusarium never was observed which would produce a typical coremium[16] or a typical pionnotes,[17] that is, the two fruiting forms on the basis of which the genera Atractium and Pionnotes were founded by their authors and which are now reduced to synonymy by Appel and Wollenweber because these investigators find in the Fusaria certain structures resembling these two forms.

That one of these forms, Pionnotes, is a distinct form, and that its characters can be used as a basis in a classification of Fusarium-like organisms, has been shown lately by Wollenweber. After citing *Fusarium* (*Pionnotes*) *udum* and its variety as instances of the Fusaria without "Fusszelle," he (1913 c: 206) says: "Beiläufig bemerkt, bilden solche Fusarien zusammen mit *F. aquaeductum* eine gute Section der Gattung, die ich Eupionnotés nenne wegen des Übergewrichtes dieser Sporenverlagerung."

There is very little doubt that a true coremial form of fructification is quite distinct, and does not occur in the species of Fusarium observed by the writer.

With respect to the present status of the genus Fusarium, some recent changes must be considered here. Wollenweber (1913 a:33) transferred from the genus Fusarium to the genus Ramularia all forms with conidia of *F. dydimum* type when chlamydospores are present.[18] The same author (1913 c:225), somewhat later, also excluded from the genus Fusarium forms with conidia of the type of *F. Willkommi* and transferred them into a new genus, Cylindrocarpon,[19] established for this purpose. Thus, in fact, all forms having cylindrical conidia or conidia with rounded ends are excluded by Wollenweber (1913 c:239) from the genus Fusarium. The genus Sepedonium Link (1809), according to Wollenweber (1913 c: 200), is only a chlamydosporial stage of *Fusarium orthoceras*.

It appears, then, from the study of the Fusarium-like organisms of potatoes (which, on the whole, represent a great diversity of forms) and also from a careful survey of the genus Fusarium as it stands in literature, that the following characters are of generic value:

[16] The terminology which is used here is the same as that of Lindau.

[17] Only one Fusarium-like organism was isolated from potatoes which produces a fruiting layer very similar to a pionnotes (*F. udum* var. *Solani*), but it is very distinct from all the other Fusaria and can be used rather to support than to disprove the above statement.

[18] In those cases in which chlamydospores are not present, Wollenweber says the fungi have a perithecial stage of the genus Mycosphærella.

[19] This genus is to include only those forms for which a perithecial stage has not yet been found. *F. Willkommi* has been connected with *Nectria galligena*.

1. Color of conidia and mycelium, never of a plain gray or black color but mostly of various brilliant hues.

2. Conidia dorsiventral,[20] attenuate, pedicellate,[21] not appendiculate, smooth, normally not constricted at the septa, distinctly three- (or more) septate,[22] acrogenous, not in chains.[23]

3. Conidiophores with single to irregularly whorled branches, never truly dichotomous nor of a strictly penicilla e or verticillate type. The conidiophores, through many times repeated branching or also by growing side by side with other conidiophores, typically give rise to macroscopically observable, dense tufts of conidiophores covered more or less deeply with a somewhat slimy mass of spores. Such fruiting bodies, tuberculate in form (sporodochia),[24] may be with or without a plectenchymic (=pseudoparenchymic), flat or wartlike base, without any differentiated enclosure.

4. Chlamydospores (endogenous, double-walled, resting bodies) terminal and intercalary, or only intercalary,[25] or none, and produced both by mycelium and by spores.

5. Mycelium composed of hyphæ which are always distinctly, but not closely, septate, and irregularly, never dichotomously, branched, the secondary branches usually thinner than the primary ones; protoplasmic content of the mycelium for the greater part plainly present and usually distinctly vacuolate. The rate of growth in artificial media, when compared with the Fusarium-like organisms studied, is comparatively high.

It must be added here, as a general remark to the characteristics of the genus Fusarium given above, that in this case, as well as in any other attempts at classification of natural phenomena, the boundaries laid down for separation of one group of phenomena from all the rest have only a relative value. Thus an organism may deviate[26] in a greater or less degree in one or a few of the characters given above, and yet, so

[20] This term is used by Appel and Wollenweber (1910).
[21] This term is used by Wollenweber (1913 c). See his key on page 219 of reference cited.
[22] Fusaria-like organisms with one-septate conidia are rare. Two such organisms were isolated from potatoes, and from over one hundred and sixty Fusaria recorded by Lindau (1908–1909 : 517–588) only seven are definitely stated to have one-septate conidia; and of these seven at least two are undoubtedly not Fusaria if the changes made in this genus by Wollenweber are considered.
[23] Microconidia may be produced in chains. This is true in case of certain Fusaria of corn and of coniferous seedlings. (See Sheldon, J. L. A corn mold [Fusarium moniliforme n. sp.]. Nebraska Agr. Exp. Sta. Rept. 17: 23–32, fig. 1. 1904.)
[24] The terminology used here is the same as that used by Wollenweber (1913 a : 24, footnote).
[25] The only Fusarium-like fungus isolated by the writer which has only terminal chlamydospores seems not to be a typical Fusarium. (See *F. cuneiforme*, key and description.)
[26] Of course a true Fusarium, evidently, in no case can be of a plain gray or black color (in mycelium and conidia as well), or have non-septateor cylindrical macroconidia with both ends rounded. (In regard to the macro- and microconidia, see page 116.) Its conidia cannot be appendiculate nor its conidiophores of a true verticillate or any other specifically peculiar type.

to speak, be a good Fusarium provided all other characters of this genus are well expressed by the organism.

VARIABILITY IN THE FUSARIA

Many of the morphological and physiological characters of the Fusaria show marked variability, and at first seem to be of such a nature as to discourage any attempt to treat these fungi on a morphological basis. Thus Smith and Swingle (1904:27), in regard to their *F. oxysporum*, say: "......This fungus showed a number of very striking variations. For this reason it is impossible to give a general description that will hold universally." And after quoting descriptions of eleven old species of Fusarium from potatoes, the authors conclude as follows (1904:51): "Judged by the above descriptions, we have had a half dozen or more species of *Fusarium* in our culture tubes, some of them 'new species,' and yet all were the product of a single spore. This does not mean that there have been in our cultures any very wonderful transmutations of one thing into another, but only that organisms respond to their environment, and that 'species descriptions' of the kind cited have not taken this fact into consideration, and consequently are worthless for scientific purposes. This is not a new idea, but it is a fact to which the attention of systematic mycologists might be directed profitably at frequent intervals."

Sometimes variability, for example in the type of conidia, is so great that a student gives up hope of determining the actual type. Thus Wilcox, Link, and Pool (1913:24) conclude their discussion on the form of the conidia produced by their fungus[27] as follows: "All sorts of stages are shown in the plate, so that each one can judge for himself, as it is possible that one who has studied a great number of species of *Fusarium* will be able to pick out the characteristic form which can be set aside for this particular species."

A great number of instances of variability in this group also could be cited easily from the species presented in this paper. But it will suffice to state here only those instances of variability which are, perhaps, most important and more or less common:

1. The type of the conidium varies in many Fusaria from micro- to

[27] *F. tuberivorum* Wilcox and Link, which according to Wollenweber (1913 c : 206) is identical with *F. trichothecioides* Wr.

macroconidia, and both sometimes are of a very diverse type even within themselves. (See *F. diversisporum.*)

2. Conidiophores often vary from mere minute projections on the side of a hyphal thread to a complex dendroid structure often of a size observable macroscopically.

3. In the Fusaria for which production of sporodochia, plectenchymic stromata, or sclerotia is typical, it sometimes happens that they are not p oduced even under apparently favorable conditions. These structures may vary in size, number, and form.

4. The presence or absence of color is an especially variable character. Changes in type of color may occur, but such changes are only apparent and in all known cases can be explained on the basis of the difference in the reaction of the medium (certain orange-red colors in acid become blue in an alkaline medium), or, when a typical color is a compound one, the change may be due to the preponderance of one or another of its elementary colors.

5. Extent of the development of aërial mycelium, zonation, rate of growth, and character of the margin of the colony, may also vary to a considerable extent.

6. Especially great variation may take place in the relative production of the different types of conidia and chlamydospores.

It might appear at first glance that the variation of these fungi is so great as to leave no firm ground for morphological treatment of the group. And yet the actual situation is far from being so hopeless. First of all, the great majority of the variations mentioned above occur, as did those observed by Smith and Swingle (1904:59), under different environmental conditions; while the variability under identical conditions usually (see also Lewis 1913:225) is very slight. Secondly, the cases of variability cited above are primarily cases of variation between presence and absence of certain characters — which is, after all, of no great importance, because when a certain character is present it is always peculiar to a specific type of organism and thus this organism can be separated from others. Then there are certain Fusaria which under almost any but extreme environmental condition remain nearly the same throughout (as *F. udum* var. *Solani* and *F. cuneiforme*). And finally, the most important character in the classification of these fungi — the type and the shape of the conidia

— is after all sufficiently stable to be used safely in a morphological treatment. Even the size of conidia, when a sufficient number of measurements is made and averaged and when only conidia of the same type are compared, is of rather surprising uniformity and stability. It is believed that every one will agree with these statements after an examination of the data presented here in the descriptions of species.

That Fusaria can be separated on a strictly morphological basis was first definitely demonstrated by Appel and Wollenweber.

RELATIVE TAXONOMIC IMPORTANCE OF DIFFERENT CHARACTERS

Usually the particular organism and the prominence and stability of a given character determines the relative importance of characters in classification. Thus, in certain cases septation of conidia may be considered as the important character. For instance, in the case of *F. dimerum* and *F. affine*, this character distinguishes these two fungi at once from all the other Fusaria, while in most other cases it is not of such importance. Presence of a continuous slimy layer of spores is the important character in the case of *F. udum* var. *Solani* where this type of fructification is especially prominent. Type of microconidia, when they are of typical occurrence and especially when they are of a peculiar type, as in the case of *F. sporotrichioides*, is also a most important character. Type of chlamydospores is an important character in general for dividing the whole genus into sections, but it usually has no specific value; and yet there is a fungus, *F. cuneiforme*, which can be set off from all the rest because of its terminal unicellular chlamydospores. Color may vary considerably, but on the whole its type is stable enough to be of considerable help in dividing Fusaria into sections, and sharp contrasts in color can often be used for specific differentiation.

In general the most useful and evidently sure basis for a natural classification of this group is the shape of the macroconidia.[28] Their dorsiventrality, the form of their apex and their basal cell, and their septation, and also their size, when properly used, are of considerable service in separation of species. The actual working value of each character can be seen from the keys.

[28] Appel and Wollenweber (1910 : 34) and Wollenweber (1913 a : 26) came to this conclusion long before the writer. See also Lewis (1913 : 225).

FORMS OF FRUCTIFICATION IN PURE CULTURES

Spores

The spores in the genus Fusarium are of two kinds: conidia, or acrogenous spores, and chlamydospores, or endogenous resting bodies. The conidia in turn may be divided into two more or less distinct types: (1) macroconidia, sickle-shaped, three- or more septate spores; and (2) microconidia, oval, non- or only one- or two-septate spores.

Before the appearance of Appel and Wollenweber's work (1910) the existence of micro- and macroconidia as two distinct types was more or less generally accepted, but in that work it was concluded (page 29) that there is only one type of conidia. The latter view is, of course, correct so far as the genetic relationship between micro- and macroconidia goes. Nevertheless, the typical presence of microconidia in certain closely related Fusaria and their typical absence in others is characteristic. Besides, whenever they are present they have a comparatively constant and often peculiar type of their own. Thus, they can be used as a good natural basis for classification of these fungi, and for that reason must be considered as a type separate from macroconidia.

In this paper the term *microconidia* is applied to all nonseptate, and seldom to one- and even to two- or three-septate, conidia of a different shape from that of the macroconidia, which are sickle-shaped and usually three- or more septate. Different forms of macroconidia are shown in figure 1 (page 112).

Chlamydospores may be borne on the ends of special lateral branches of the mycelium (terminal chlamydospores), or they may be intercalary. They often are produced in the ends of the conidiophores, in the conidia or in the ends of special branches from the conidia. The chlamydospores are single, in short to long chains or in more or less large clusters. They are of common, though not of general, occurrence, and in a number of Fusaria both terminal and intercalary chlamydospores are present; in some others there are only terminal, and in still others only intercalary chlamydospores have been observed. A number of Fusaria evidently have no true chlamydospores; they may possess structures with dense content, but these structures are not thick, double-walled bodies.

Forms of fructification

Sometimes, as in the case of the conidia on aërial mycelium of *F. trichothecioides*, and also in the sporotrichial form of *F. sporotrichioides*,

the conidia are borne singly and remain thus in the form of a powder. Usually, however, they adhere to the tips of conidiophores for a time, forming balls of variable size. This may be the case with microconidia as well as with macroconidia. In certain Fusaria, such as *F. cuneiforme*, and in all members of the section Martiella, these balls of conidia are especially prominent; but they are very common also in the other Fusaria and therefore cannot be used for specific differentiation.

When there is no room for old conidia to be pushed aside — that is, when the fruiting branches are very numerous and close together — a considerable and continuous mass of spores results; these, when the air is moist, form a roundish, wartlike heap of spores, which, with the conidiophores producing them, is known as a **sporodochium.** When the air is comparatively dry, the spores are pushed up in more or less curled, long, tendril-like columns. This is often observed especially in many cultures on sterilized canes of red raspberry and in stem plugs of other plants.

Often small sporodochia are produced on and strewn all over the aërial mycelium, producing a picture very characteristic for *F. subulatum* and some other Fusaria. In other cases minute and numerous sporodochia are produced very close to or on the surface of the substratum, and when these minute sporodochia are very numerous they form a nearly continuous, slimy layer of conidia. The fructification then resembles a pionnotes and is called here **pseudopionnotes.** In one case a seemingly true pionnotes[29] — that is, a thick, continuous, slimy layer of spores — was observed (in *F. udum* var. *Solani*). A pseudopionnotes may be produced under aërial mycelium which may more or less mask its macroscopic appearance, as in the case of several Fusaria of the section Elegans; but in certain cases there is no aërial mycelium over it, and the pseudopionnotes remains fully exposed and characteristic for certain species. (See *F. metacroum*, *F. falcatum*, and *F. discolor* var. *sulphureum*.)

Mycelial threads in many Fusaria often run parallel and anastomose more or less closely, thus producing a ropelike structure which may come up into the air in an irregular fashion and which also may bear more or less abundant conidia produced on side branches. These ropelike structures then resemble coremia, which are columnar fruiting bodies, typical of the family Stilbaceæ. No true coremia were observed in any of the Fusaria presented here.

[29] The definition is taken from Lindau (1908–1909 : 509).

A stroma, in the sense employed here,[30] is the fungous layer on which aërial structures (aërial mycelium, conidiophores, and spores) are produced. The stroma may consist of more or less loose hyphæ, or it may form a dense pseudoparenchymic (plectenchymic), continuous sheet, fleck, or prominent wart. There are often produced also roundish, more or less wrinkled, often shiny, bodies, resembling true sclerotia. They are of a dark blue color, and among the Fusaria studied in the course of this work they were observed only in certain species of the section Elegans; though according to Wollenweber (1913 a:32) they are very common also in the section Roseum, and are characteristic for one species, *F. sclerotium* Wr., of the section Gibbosum.

METHOD OF STUDY AND PRESENTATION

The method actually employed in this work consisted in the cultivation of pedigreed strains of the various organisms on various natural and artificial media. Almost without exception, all the strains were transferred to a new medium on the same day and the whole set of cultures was kept under the same environmental conditions. In all important cases duplicate cultures were employed. For the inoculum, as far as possible, similar material was used — that is, only mature spores or only aërial or only submerged mycelium. The importance of the same environmental conditions for a comparative study is evident. It applies equally as well to the kind of inocula used, as it was found[31] that often an inoculation made with spores tends to better spore production, and an inoculation with mycelium often results mainly, at any rate at first, in the production of mycelium.

In order to bring all cultures to the same stage of maturity and also to assure their purity, dilutions in poured plates were made again and again for the entire set of the Fusaria (of isolations made by the writer, as well as of the organisms obtained in culture from other sources), and then new transfers were made from colonies about two days old produced in the plates.

In the macroscopical examination of the culture, special attention was given to the presence or the absence, and the character, of aërial mycelium; to the kind of fructification layer (pionnotes-like, sporodochial, and so forth); to the color of spores, of aërial and submerged mycelium, and of

[30] A slightly different definition of stroma is given by Wollenweber (1913 a: 24, footnote).
[31] See Appel and Wollenweber (1910: 13), and also Lewis (1913: 209). The same was frequently found to be the case also in the course of this work.

substratum; and to the production of special structures such as plectenchymic stromata and sclerotia.

In the microscopical study, the different types of conidia, chlamydospores, and conidiophores received special attention. The observations were recorded by means of camera lucida drawings[32] and necessary measurements.

When measurements were of any importance,[33] ten conidia (or chlamydospores) were measured and only the average and the extremes of these measurements were recorded. In cases of special variability of the material, records were made of fifteen or twenty spores of each important type of septation and shape.

In making camera lucida drawings, care was taken to picture the apical and the basal ends of the conidia with the utmost accuracy; every kind of conidium occurring in a culture was drawn, but the typical and the exceptional cases, as they appeared, were marked off.

As a rule, measurements and drawings usually were made of the conidia taken from sporodochial or pionnotes-like masses of them, because such conidia on the whole are more uniform and typical for a given organism. Here it should be noted that for the measurements and drawings it is highly important, at least in case of very closely related organisms, to use material analogous in all respects — age, type of fructification, and environmental condition.

The fungi were studied, not only on different media, but also at different stages of their growth. The latter factor is almost as important as the former, because in certain cases, as in *F. angustum*, conidia in the best condition (most regular, and so forth) were observed when the cultures were very young. Some characters, however, become manifest only after a culture has reached a certain stage of maturity. This is often the case with chlamydospores and color production. Sclerotia often appear in comparatively old cultures and continue to grow for some time.

The presentation of the species of Fusarium is based on the following main principles:

All drawings (with only a few exceptions) are intentionally made to the same scale as those of Appel and Wollenweber — thus far the one

[32] All drawings were made from living material mounted in water, and, with a few exceptions, with an oil immersion lens. In order to prevent movement of the spores in water, it is necessary first to use just enough water to keep air from underneath the cover glass, and then to spread around the cover glass some oily substance, as cedar oil, which does not dissolve in water and which does not dry out quickly.

[33] A number of fields should be examined before measuring in order to see the prevailing type, and then measurements of the conidia of the prevailing type should be taken. This leaves much to personal interpretation, but otherwise it would be necessary to take many more measurements.

fundamental work on this subject[34] — so that comparison can be made easily. The drawings represent all types of conidia, abnormal ones included, so that no one may be misled by types actually observed by him and by those given here. This might easily be the case if only normal material were presented, because our understanding of what is normal is very relative, is often too broad, and seldom corresponds to the things as they are. The particular forms that seemed to be normal are indicated by the drawings in figure 1 (page 122).

Usually no attempt was made to represent the structure of the cell content, because it was not considered of taxonomic value. In those few cases in which the structure of the plasma seemed to be characteristic it is shown in a very approximate way.

The microscopical character of the mycelium, so far as observed by the writer, cannot be used for specific differentiation of these fungi; therefore no attention has been given it, either in drawings or in measurements, except in a very few instances when certain striking peculiarities have been so recorded (Figs. 34M and 43L).

In giving measurements of the size of spores, it was considered necessary, first, to give an average size for conidia from a particular culture, as well as the average of the measurements for the entire series of cultures. Thus the measurements have a definite meaning and are comparable with one another, provided the measurements are taken separately for each type of spore.

In arranging the species according to their relationship it was found convenient to follow Wollenweber's example (1913 a:26–27), and divide all the Fusaria into sections. Most of the sections are the same as those of Wollenweber, but because of some organisms presented here that could not be placed in any of his sections, certain new sections have been established provisionally.

In connection with taxonomic study and presentation of the Fusaria, it is necessary to discuss, at least briefly, the conception of the so-called normal culture. The observations of the writer in this regard are principally of the same nature as those of Appel and Wollenweber (1910:21–22) and can be summarized as follows:

1. A culture can be in the state of undevelopment (*Ankultur*) when the growth shows mycelium to the entire exclusion of, or to an abnormally

[34] It is firmly believed that standardisation of the subject presented is especially important in the study of this difficult group of fungi.

poor production of, spores; other forms normally present in the culture may also be absent. This state of culture may sometimes exist when a fungus is transferred from a mycelial growth, especially when it is taken directly from host tissues.

2. A culture is considered to be a normal one (*Normkultur*) when all forms typical to the fungus — and especially the most important form, the macroconidia — are abundant, comparatively uniform in size and shape, smooth in outline, and so forth.

3. After a long cultivation on artificial media, a fungus may lose certain characters, such as ability to produce certain color and also its virulence as a parasite. Such a state of culture is that of degeneration (*Abkultur*), and it may be accompanied also by smaller size and abnormal septation of the conidia. (Only loss of color was observed by the writer; the other observations are those of Appel and Wollenweber, 1910:22.)

4. In the first period of growth of any one of the Fusaria, the first conidia produced usually soon begin to produce new conidia, sometimes on minute papillæ located directly on the conidial walls, and sometimes on more or less well-differentiated and well-developed conidiophores, the process often much resembling the budding process in yeasts. In such young cultures the conidia are more or less swollen, their contents are commonly densely granular, and septation is not clear. This period (*Jungkultur*) may last from one to five or more days.

5. After the period just described, the fungus, when in normal condition, produces conidia which remain for a greater or a less length of time, of perfectly smooth outline and with clear septation. At this state of maturity (*Hochkultur*) the conidia are also of most uniform and typical shape and size, and it is the important stage for taxonomic study of these organisms.

6. Finally there comes a period (*Altkultur*) in which the conidia begin to disintegrate through the process of self-digestion, or at least become of less uniform and perfect type, and after a period of time the culture begins to lose its vitality.

These variations in character of the cultures show that only normal and mature cultures must be considered, though the character of other conditions may also give some help in identification. Another point which must be clear from the account given above is that in the study of these fungi they must be grown for a long period of time, under different cultural conditions and from different kinds of material for inocula. Then, after

observation of all the stages, it will be possible to pick out easily the typical and normal one and base judgment mainly on that. Most minute attention must be paid to the shape of macroconidia.

In order to avoid much of the possible confusion in regard to the color production by the fungi, it will perhaps be not out of place to mention again that a convenient standard of colors must be used. Ridgway's (1912) color standards have been used in this work.

IDENTIFICATION OF THE FUSARIA WITH PREVIOUSLY DESCRIBED SPECIES

An identification of the Fusaria of potatoes with Fusaria formerly described as occurring on other substrata and even on potatoes, is in most cases impossible or at least rather doubtful. The species have been described mostly from material as it was collected in nature. After what has been said in the foregoing pages about variability of the Fusaria, about their common occurrence in different, often abnormal, stages, about the necessity of most minute attention to the peculiarity of the shape of the macroconidia, and about the importance of good drawings and of measurements properly made and presented, it can easily be seen what small chance there is of identifying an organism from any typical description of one of these species. The figures are often absent, and when present they are either too schematic or so inaccurate that they might just as well be omitted. Any citation in support of this statement would be superfluous.[35]

There are a number of different Fusaria which agree with a certain description and therefore might be considered as the same species. At the same time the very same organism may have other characters which, if studied alone, would surely set it off as a distinct species. An extensive illustration of this state of affairs is given by Appel and Wollenweber (1910:9–12), but the most impressive case is that of Smith and Swingle (1904:50–51). Therefore, although the literature on the subject was fully examined, especially publications of descriptions supplemented by any kind of illustrations, usually no definite conclusion in regard to identity could be arrived at. Because of this, and also because the most important literature is already listed in a few works on this subject (especially by

[35] Appel and Wollenweber (1910:12) in this connection made the following statement: "Oft blieb uns daher weiter nichts übrig, als neue Namen zu geben und ihnen so genaue Beschreibungen beizufügen, dass nunmehr die Arten immer wieder erkannt werden können."

Appel and Wollenweber in 1910, and by Wollenweber in 1913), this literature is usually not cited and a bibliography is omitted.

The condition of the taxonomic literature on species of the genus Fusarium in general is characterized by Wollenweber (1913 a:41) as presenting "an almost hopeless confusion." The only favorable exceptions known to the writer are the works of Wollenweber, alone and in association with other authors. These works are fully considered here. In fact there is hardly any difficulty in recognizing Fusaria described by Wollenweber. Nevertheless all available cultures of his organisms were grown along with the other Fusaria, and a thorough comparison of living material was made whenever it was necessary.

When this work was actually completed there appeared the work of Lewis (1913) on certain disease-producing species of Fusarium. The work was supplemented also with Wollenweber's list of the names for the fungi studied by Lewis, and also with certain remarks by Wollenweber in regard to the taxonomy of those organisms. It appeared that certain of Lewis's organisms were the same as those isolated by the writer from potatoes. Cultures of four Fusaria, somewhat resembling certain species isolated from potatoes, were obtained by the writer through the courtesy of Dr. Morse, Plant Pathologist in the Maine Agricultural Experiment Station. On comparison these four organisms — *F. pirinum* (Fries) Sacc., *F. conglutinans* Wr., *F. citrinum* n. sp., and *F. argillaceum* (Fries) Sacc.— were found to be distinct from all Fusaria presented here.

SYSTEMATIC ARRANGEMENT OF THE SPECIES OF FUSARIUM OF POTATOES

The natural key to the species and their arrangement in sections,[36] as given here, are in the main similar to those of Appel and Wollenweber (1910:59–60) and of Wollenweber (1913 a:28–32), respectively. Some changes and additions have been made, however, in order to include many new organisms.

Variety is used as the smallest unit in the taxonomic treatment of these fungi. An organism is classed as a variety if it differs from the closely related species in only one character, even though the difference be conspicuous; the same treatment holds with respect to the organisms that differ slightly in a few characters. When the differences are slight, but in several important characters, the organisms are classed as distinct

[36] The term is used by Wollenweber (1913 a: 28).

species. In general it was preferred rather to name a possibly good species as a variety than to raise a mere variety to specific rank.

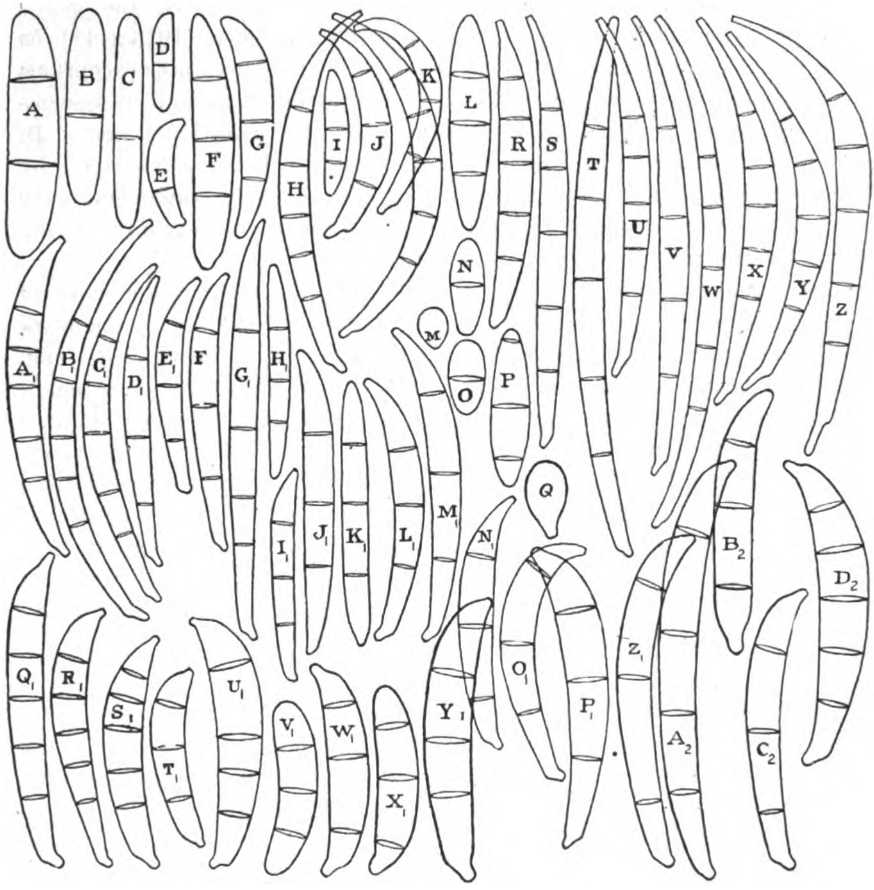

FIG. 1.— *Types of conidia of the species of Fusarium and Fusarium-like fungi found on potatoes.* A, *Ramularia Solani;* B, *R. eudidyma;* C, *R. Magnusiana;* D, *Fusarium affine;* E, *F. dimerum;* F, *F. cuneiforme;* G, *F. udum var Solani;* H, I, J, *F. ferruginosum;* K, *F. sanguineum var. pallidium;* L, M, N, O, P, *F. arthrosporioides;* Q, *F. sporotrichioides;* R, S, *F. arthrosporioides var. asporotrichius;* T, *F. anguioides:* U, *F. biforme;* V, *F. lucidum;* W, *F. subulatum;* X, *F. falcatum;* Y, *F. gibbosum;* Z, *F. caudatum var. Solani;* A_1, *F. bullatum;* B_1, *F. arcuosporum;* C_1, D_1, E_1, *F. truncatum;* F_1, *F. lutulatum;* G_1, H_1, *F. angustum;* I_1, J_1, K_1, *F. orthoceras;* L_1, *F. oxysporum var. resupinatum;* M_1, *F. oxysporum var. longius;* N_1, *F. oxysporum;* O_1, *F. sclerotioides;* P_1, *F. redolens var. Solani;* Q_1, *F. discolor;* R_1, *F. clavatum;* S_1, T_1, *F. subpallidum var. roseum;* U_1, V_1, *F. trichothecioides;* W_1, *F. discolor var. triseptatum;* X_1, Y_1, *F. Solani;* Z_1, A_2, *F. Martii;* B_2, *F. coeruleum;* C_2, *F. striatum;* D_2, *F. culmorum var. leteius. Magnification 1000 times*

DICHOTOMOUS KEY TO THE SPECIES OF FUSARIUM AND FUSARIUM-LIKE FUNGI OF POTATOES

Page
a. Conidia [27] not typically dorsiventral, apex rounded, apedicellate.......RAMULARIA 264
b. Conidia typically one-septate
c. Average diameter of one-septate conidia 4.9 μ................*R. eudidyma* 264
cc. Average diameter of one-septate conidia 3.9 μ................*R. Magnusiana* 265
bb. Conidia typically two-septate..*R. Solani* 267
aa. Conidia typically dorsiventral, apex more or less attenuate, mostly pedicellate FUSARIUM 125
b. Conidia typically one-septate, three or more septa never present..Section Dimerum 125
c. Ventrally straight..*F. affine* 126
cc. Ventrally curved..*F. dimerum* 127
bb. Conidia typically three- or more septate
c. Dorsiventrality slight..................................Section Ventricosum 128
d. Chlamydospores terminal only..............................*F. cuneiforme* 129
dd. Chlamydospores terminal and intercalary....................*F. ventricosum* 128
cc. Dorsiventrality distinct
d. Conidia apedicellate, true pionnotes present...Section Eupionnotes. *F. udum* 131
dd. Conidia pedicellate, true pionnotes absent
e. Conidia with gradually attenuated, pointed apex
f. Conidia prominently broader in the middle, apex long and narrow, most prominently pedicellate..........................Section Gibbosum 133
g. Dorsally more or less hyperbolic.......................*F. gibbosum* 133
gg. Dorsally more or less elliptic
h. Aërial mycelium poorly developed, fruiting layers in form of a pseudopionnotes.......................................*F falcatum* 135
hh. Aërial mycelium well developed
i. Conidia typically five-septate.............*F. falcatum* var. *fuscum* 138
ii. Conidia typically five- to seven-septate.....*F. caudatum* var. *Solani* 140
ff. Conidia of about equal diameter for a more or less considerable part of their length, apex not very long
g. Conidia typically five-septate; typical color of conidial masses red, of substratum pink to orange and brown-red; no terminal chlamydospores
h. Chlamydospores absent
i. Microconidia typically absent..................Section Roseum 142
j. Blue sclerotia present.........................*F. acuminatum* 142
jj. Blue sclerotia absent
k. Conidia typically in pseudopionnotes; aërial mycelium weakly developed or absent.......................*F. metacroum* 143
kk. Conidia typically in distinct sporodochia; aërial mycelium well developed
l. Sporodochia small, borne on aërial mycelium and without plectenchymic base......................*F. subulatum* 147
ll. Sporodochia large, with plectenchymic base
m. Six-septate conidia typically present.........*F. effusum* 151
mm. Six-septate conidia typically absent
n. Five-septate conidia dominant type........*F. lucidum* 157
nn. Three- and five-septate conidia about equally present, or three-septate dominant.............*F. truncatum* 155

[27] The term *conidia* is used here, in this key and elsewhere, in the sense of macroconidia.

Page

ii. Microconidia typically present, usually spindle-shaped, non- to three-septate........................Section Arthrosporiella 161
j. Six- to seven-septate conidia typically present, at least in pseudo-pionnotal stage
k. Distinct sporodochia present
l. Substratum and aërial mycelium near it typically of carmine hues, causal layer of aërial mycelium pink......*F. biforme* 166
ll. Substratum of a clay color, aërial mycelium white......... *F. diversisporum* 161
kk. No conspicuous sporodochia, fruiting layer on moist media commonly in form of a pseudopionnotes.......*F. anguioides* 169
jj. Six- to seven-septate conidia absent.........*F. arthrosporioides* 175
hh. Chlamydospores present, typically intercalary only
i. Microconidia present, pyriform............Section Sporotrichiella 183
F. sporotrichioides 183
ii. Microconidia absent or not pyriform.......Section Ferruginosum 186
j. Typical macroconidia of about equal diameter for a considerable length, or not prominently broader in the middle, in some cases approaching the subulatum type, much curved
k. Chlamydospores typically only in mycelium
l. Chlamydospores sparse, never in masses nor in long chains.. *F. arcuosporum* 186
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DESCRIPTIONS OF SECTIONS, GENERA, SPECIES, AND VARIETIES

FUSARIUM Link

Link, Mag. Ges. nat. Freunde 3:10. 1824. Saccardo, Syll. Fung. 4:694. 1886. (Cf. Appel. O., and Wollenweber, H. W., Arb. K. biol. Anst. Land- u. Forstw. 8:60–61. 1910. Wollenweber, H. W., Phytopath. 3:24–50, 197–240, fig. 1, Pls. I and III. 1913; Ber. deut. Bot. Gesell. 31:17–34. 1913. Journ. Agr. Research 2:251–285. 1914.)

Hyphomycetes, with from hyaline to bright, but never plain gray nor black, conidia and mycelium; conidia sickle-shaped, septate (usually 3- or more septate), apically pointed, mostly pedicellate, not appendiculate, noncatenulate; conidia scattered over substratum, in pseudopionnotes or in sporodochia, the latter without or with from flat to wart-like plectenchymic substratum, and always without any differentiated enclosing or surrounding structures; conidiophores from simple to irregularly verticillate.

I. SECTION DIMERUM n. sec.

Conidia dorsiventral, 1-septate; chlamydospores may be present.

This section is proposed in order that Fusaria with 1-septate conidia may be included. The two species of this section are comparatively

slow-growing fungi, with hyaline or nearly hyaline mycelium and from hyaline to orange-colored conidia. They appear to differ in many ways from typical Fusaria, but the differences are not sharp enough to warrant transferring them into another genus.

1. *Fusarium affine* Faut. et Lamb. (Figs. 1D and 2)

Fautrey, F., and Lambotte, E., Espèces nouvelles ou rares de la Côte-d'Or, Rev. Myc. Fr. 18:68. 1896. Saccardo, Syll. Fung. 14:1125. 1899.

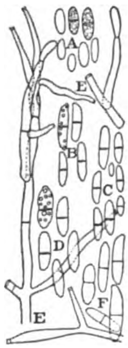

FIG. 2.—*Fusarium affine.* A, *Conidia from 35-days-old culture on slightly acidified potato agar;* B, *conidia from 7-days-old plate culture on hard potato agar;* C, *conidia from 74-days-old culture on red raspberry cane plug;* D, *conidia from 4-days-old culture on hard lima-bean agar;* E, *conidiophores from various media;* F, *conidia from 5-days-old culture on nutrient agar*

Conidia straight, somewhat dorsiventral near apex, apedicellate, typically 1–septate, 10.2 x 2.8 (9–11.4 x 2.6–3)μ, usually in a continuous smooth or slightly roughened, slimy layer, from hyaline to pale salmon-colored on a glucose agar; conidiophores from simple to sparingly branched, septate; mycelium hyaline; no chlamydospores.

Hab. In tubers and stems of *Solanum tuberosum,* in greenhouse soil, New York.

This organism was repeatedly isolated from various sources such as discolored fibrovascular bundles of potato tubers, from the base of wilted potato stems, and from soil. Its size is exactly the same as that given by Wollenweber (1913 c:229) for the conidial stage of *Mycosphaerella Solani* (E. et E.) Wr. Wollenweber's illustrations (Plate XXI, fig. N) are also much the same, and he considers *F. affine* Faut. et Lamb. as the conidial stage. The strain studied did not show any perfect form in culture, although it was grown for more than a year and on various media. This organism can be at once distinguished from all the other Fusaria by its minute, 1–septate, nearly straight conidia and its inconspicuous, slow growth.

For a fuller presentation of its septation and size the following detailed measurements are given:

On red raspberry cane plug, culture seventy-four days old:

Conidia: 0–septate, 45 per cent, 7 x 2.2 (3.5–9 x 1.7–2.6)μ
1–septate, 55 per cent, 9 x 2.6 (6–12 x 2–3)μ

On hard lima-bean agar, culture four days old:
Conidia: 0–septate, 40 per cent
1–septate, 60 per cent, 10.2 x 3 (9–11 x 2.8–3.8)μ

On nutrient agar, culture six days old:
Conidia: 0–septate, 10 per cent
1–septate, 90 per cent, 11.4 x 2.8 (8.7–13 x 2.4–3.5)μ

Average of the above measurements:
Conidia: 0–septate, 32 per cent, 7 x 2.2μ
1–septate, 68 per cent, 10.2 x 2.8μ

The size of the spores of *F. affine* as given by Saccardo (10–15 x 4μ) differs somewhat from the above, but the description otherwise is so much the same that the organisms can be considered identical.

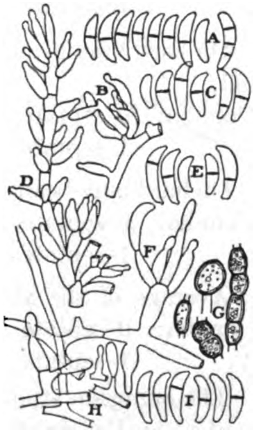

FIG. 3.—*Fusarium dimerum.* A, *Pseudopionnotal conidia from 70-days-old culture;* B, *conidiophore,* C, *pseudopionnotal conidia, from 19-days-old culture on slightly acidified hard potato agar;* D, *conidiophore from 70-days-old culture on potato stem plug;* E, *conidia,* F, *conidiophore, from 43-days-old culture on hard lima-bean agar with 2 per cent glucose;* G, *chlamydospores;* H, *conidiophores,* I, *conidia, from 21-days-old culture on hard lima-bean agar*

2. *Fusarium dimerum* Penz. (Figs. 1E and 3)

Penzig, O., Michelia 2:484. 1882. Saccardo, Syll. Fung. 4:704. 1886. Lindau, Rab. Krypt. Fl. Pilze 9:566. 1910. Appel and Wollenweber, Arb. K. biol. Anst. Land- u. Forstw. 8:37, text figs. 2 and 4. 1910.

Conidia lunar, somewhat pedicellate, typically 1–septate, 13 x 3.3 (12.5–13.5 x 3.3–3.4)μ, often also 0–septate, rarely 2– or 3–septate, borne singly on the mycelium or forming a more or less continuous slimy layer, from hyaline to cinnamon-buff on glucose agar; mycelium from hyaline to about the color of the conidial masses; chlamydospores intercalary, in mycelium.

Hab. On tubers and stems of *Solanum tuberosum* in Germany and in Minnesota (U. S. A.), and on fruits of *Citrus medica* in Italy.

The fungus is easily distinguished from all the other Fusaria by its lunar, minute, 1–septate conidia. It was isolated by the author only once, from a superficial dry rot of potato tuber received from St. Paul, Minnesota.

The measurements of the conidia in detail are as follows:

On hard potato agar, slightly acidified, culture eighteen days old:
Conidia: 0–septate, 3 per cent
1–septate, 97 per cent, 12.5 x 3.4 (10–18 x 2.9–4.1)μ

On hard lima-bean agar with 2 per cent glucose, culture forty-three days old:
Conidia: 0–septate, 12 per cent, 10 x 3.8μ
1–septate, 88 per cent, 12 x 3.3 (10–18 x 3–3.5)μ

On hard lima-bean agar, culture twenty-one days old:
Conidia: 0–septate, 27 per cent, 11.5 x 3.2 (9–14 x 2.9–3.5)μ
1–septate, 73 per cent, 12.5 x 3.3 (10–17 x 2.9–3.9)μ

Average of the above measurements:
Conidia: 0–septate, 14 per cent, 10.8 x 3.5μ
1–septate, 86 per cent, 12.8 x 3.3μ

The organism studied is so much the same as *F. dimerum* originally described by Penzig, that it is considered identical. A similar organism is also reported as occurring on potato in Germany (Appel and Wollenweber, 1910:37). The only peculiarity of the organism which either was not observed or was not present at all in the original *F. dimerum* is that the septum in the conidia of the organism studied is often and conspicuously acentric.

II. SECTION VENTRICOSUM Wr., Phytopath. 3:32

Conidia only slightly dorsiventral, somewhat wedge-shaped, broader toward base, apex somewhat rounded, apedicellate, typically 3–septate; no sporodochia; chlamydospores variable,[88] always present.

3. *Fusarium ventricosum* Ap. et Wr.

Wollenweber, H. W., Phytopath. 3:32, fig. 1, A and V. 1913.

Wollenweber describes this species as follows: "Conidia never formed in sporodochia, brownish-white to cream-colored, 3–septate, 29–37 x 5.75–7.5μ; conidiophores bostryx-like or irregularly branched, chlamydospores like those of the section Elegans. Wound parasite, ... found in Europe. Inhabits also *Beta vulgaris*."

The organism was neither isolated nor studied by the writer.

[88] According to Wollenweber the chlamydospores are of Elegans type, that is, terminal and intercalary, 0- to 1- or more septate. In order to include *F. cuneiforme* it was necessary to alter the characterization of the chlamydospores in this section.

4. Fusarium cuneiforme n. sp. (Figs. 1 F and 4)

Conidia only slightly dorsiventral, more or less wedge-shaped, broader toward the base, with apex somewhat rounded, apedicellate, typically 3-septate, 34.7 x 5.6 (30–41 x 5.6–6)μ, often 0- to 2-septate, in false balls, from hyaline to cream-colored; no sporodochia; aërial mycelium hyaline, in a high tuft in center, and short, distinctly zonate, outside; chlamydospores from smooth to very distinctly warted, sometimes surrounded with a gelatinous capsule, terminal only, typically unicellular, 8.2 x 7.6 (7.6–8.5 x 7.3–8.1)μ.

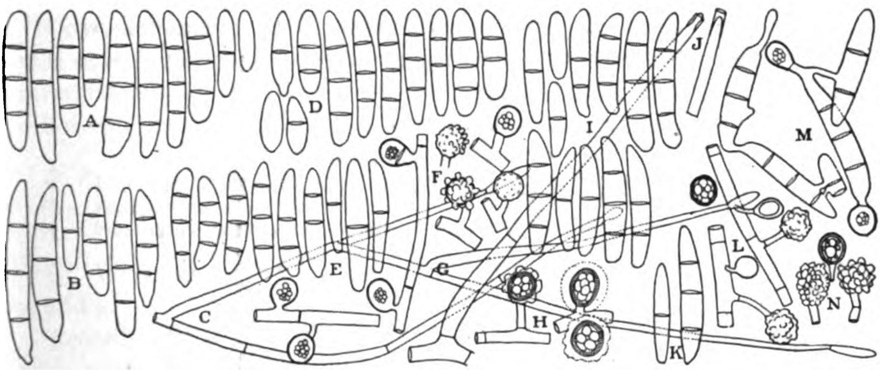

FIG. 4.—*Fusarium cuneiforme.* A, *Conidia from false balls of 16-days-old culture on slightly acidified hard potato agar;* B, *conidia from false balls from 10-days-old potato agar with 0.5 per cent glucose;* C, *conidiophores,* D, *conidia, from a thin layer of 73-days-old culture on red raspberry cane plug;* E, *conidia from confluent thin mass of false balls of 64-days-old culture on hard bean agar;* F, *terminal chlamydospores,* G, *conidiophore, from 34-days-old culture on hard lima-bean agar;* H, *terminal chlamydospores of 16-days-old culture on slightly acidified hard potato agar;* I, *conidia,* J, *tips of conidiophores showing beginning of production of new conidia, from 34-days-old culture on hard lima-bean agar;* K, *conidia,* L, *terminal chlamydospores, from 26-days-old corn agar;* M, *anastomosis, and chlamydospore producing conidia from 34-days-old culture on hard lima-bean agar;* N, *terminal chlamydospores from the same culture*

Hab. The fungus was isolated from soft rotted potato tubers received from Auburn, Alabama, and from Atlanta, New York, always in association with bacteria and other fungi.

Differs from *F. ventricosum* Ap. et Wr. mainly in typically 0-septate chlamydospores which are terminal only. There seems to be some difference also in the shape and size of the conidia, which here are somewhat more slender.

Latin description.—Conidiis parum dorsiventralibus, plus minusve cuneiformibus, deorsum latioribus, apice subrotundato, apedicellatis, typice 3–septatis, 34.7 x 5.6 (30–41 x 5.6–6)μ, 0–2–septatis, globis falsis, ex hyalino "cream color" (R); nullis sporodochiis; aerio mycelio hyalino, medio alte cristato, extra brevi et distincte zonato; chlamydosporis levibus vel maxime distincte verrucosis, interdum capsula gelatinosa cinctis, tantum terminalibus, typice unicellularibus, 8.2 x 7.6 (7.6–8.5 x 7.3–8.1)μ.

Hab. Fungus ex tuberibus mollibus putridisque Solani tuberosi ab Auburn, Alabama, et Atlanta, New York, Amer. bor. receptis, semper una cum bacteriis aliisque fungis, sejungebatur.

The measurements of conidia on different media are as follows:

On slightly acidified hard potato agar, culture sixteen days old:

Conidia: 0–septate, rare, 16 x 4μ
1–septate, rare, 21 x 5.2μ
2–septate, 1 per cent, 24 x 5.6 (20–32 x 5.2–5.8)μ
3–septate, 99 per cent, 35.5 x 6 (24–44 x 4.7–7.5)μ

On red raspberry cane plug, culture seventy-three days old:

Conidia: 0–septate, 12 per cent, 14 x 5.9 (6.5–17 x 5–6.5)μ
1–septate, 34 per cent, 19 x 6 (15–27 x 4.8–7)μ
2–septate, 11 per cent, 33 x 5.9 (20–40 x 5.2–6.5)μ
3–septate, 43 per cent, 33 x 5.9 (20–40 x 5.2–6.5)μ

On hard potato agar, culture twenty-five days old:

Conidia: 1–septate, rare
3–septate, 100 per cent, 35 x 5.8 (24–48 x 5–6.5)μ

On hard lima-bean agar with 2 per cent glucose, culture sixty-four days old:

Conidia: 0–septate, 4 per cent
1–septate, 64 per cent, 25 x 4.9 (12–41 x 3.5–6.5)μ
2–septate, 22 per cent, 28 x 5.5 (23–32 x 4.8–5.9)μ
3–septate, 10 per cent, 30 x 5.6 (24–38 x 4.8–6.2)μ

On hard lima-bean agar, culture thirty-four days old, advanced part of colony growth:

Conidia: 0–septate, rare
1–septate, 17 per cent
2–septate, 7 per cent
3–septate, 76 per cent, 31.5 x 6 (27–41 x 5.2–7.6)μ

On same culture as above but from an old part of the colony growth:
3–septate, 70 per cent, 41 x 6 (36–46 x 5.2–7.6)μ

Average of the above measurements:
Conidia: 0–septate, 3 per cent, 15 x 5μ
1–septate, 23 per cent, 21.3 x 5.4μ
2–septate, 8 per cent, 26 x 5.45μ
3–septate, 66 per cent, 34.7 x 5.9μ

III. SECTION EUPIONNOTES Wr., Phytopath. 3:38, 206, 219

Conidia dorsiventral, apedicellate, nearly cylindrical for the largest part or slightly broader toward apex, typically 3–septate, in true pionnotes; terminal and intercalary chlamydospores present. Differs from all the other sections of Fusaria by true pionnotal fruiting form.

5. *Fusarium udum* (Berk.) Wr.

Syn. *Fusisporium udum* Berk., Ann. Mag. Nat. Hist. 6:438, Pl. XIV, fig. 28. 1841.
Pionnotes uda (Berk.) Sacc., Syll. Fung. 4:726. 1886.

Cf. Wollenweber, Phytopath. 3:38 (footnote), 219 (key), Pl. XXI, figs. R and S.

According to Wollenweber's data and figures, the conidia are dorsiventral with somewhat rounded apex, apedicellate, typically 3–septate, about 33–45 x 3.5–4μ, sometimes 4– or 5–septate; terminal chlamydospores present.

Hab. On cut surfaces of oak, elm, and other trees, also on *Solanum tuberosum*, on tulip bulbs, and in the soil.

6. *Fusarium udum* (Berk.) Wr. var. **Solani** n. var. (Figs. 1G and 5)

Conidia dorsiventral, usually somewhat broader toward the slightly rounded apex, apedicellate, typically 3–septate, 30.2 x 4.27 (25–34 x 4–4.5)μ, non– to two–septate very rare when mature, 4– and 5–septate rare, of from light vinaceous cinnamon to orange-cinnamon hues on agars rich in glucose; chlamydospores usually found only in old cultures, terminal and intercalary, in conidia, in the tips of sterigmata, and in mycelium, often of dense orange color, 0–septate, 6 x 5.5μ; aërial mycelium present only near margin of colony growth, very loose, short, hyaline; substratum colorless or approaching the color of the conidia.

Hab. On rotted tubers of *Solanum tuberosum*, together with *Ramularia Solani*, Long Island, New York.

Differs from *F. udum* (Berk.) Wr. in that the conidia are shorter and thicker, and somewhat broader toward the apex.

The following measurements were taken:

On slightly acidified hard potato agar, culture eight days old:

Conidia: 0– and 1–septate, only when young
3–septate, 100 per cent, 33 x 4.25 (28–39 x 3.5–4.7)μ

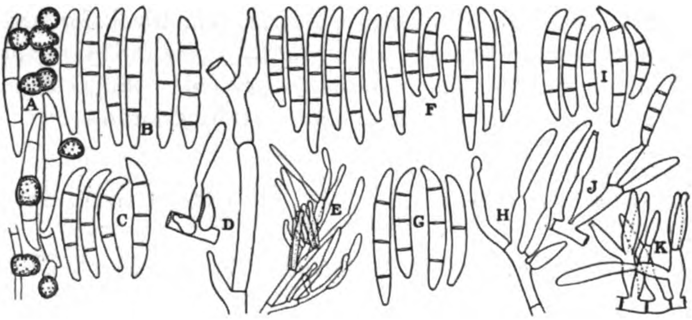

FIG. 5.—*Fusarium udum var. Solani.* A, *Different forms of chlamydospores from 85-days-old culture on hard potato agar with 5 per cent glucose;* B, *conidia from 9-days-old culture on hard lima-bean agar;* C, *conidia,* D, *conidiophores, from 49-days-old culture on rye straw;* E, *conidiophores (magnified 250 times) from 8-days-old culture on slightly acidified hard potato agar;* F, *conidia from 72-days-old culture on potato tuber plug;* G, *conidia,* H, *conidiophores, from 8-days-old culture on slightly acidified hard potato agar;* I, *conidia,* J, K, *conidiophores, from 74-days-old culture on red raspberry cane plug*

On red raspberry cane plug, culture seventy-four days old:

(1) From an advanced part of colony growth

Conidia: 1–septate, rare
2–septate, 10 per cent, 22 x 3.8 (19.5–24 x 3.3–4.1)μ
3–septate, 90 per cent, 25 x 4 (22–31 x 3.9–4.6)μ

(2) From an old part of colony growth

Conidia: 3–septate, 100 per cent, 28 x 4μ dominant type
4–septate, rare

On potato tuber plug, culture seventy-two days old:

Conidia: 0–septate, rare, young
1–septate, 5 per cent, mostly young
2–septate, 2 per cent, mostly young
3–septate, 86 per cent, 31 x 4.4 (23–40 x 3.9–4.7)μ
4–septate, 7 per cent, 32 x 4.4 (28–40 x 4.1–4.7)μ
5–septate, rare, 35 x 4.4 (30–40 x 4–4.6)μ

On hard lima-bean agar, culture four days old:

Conidia: 1–septate, 1 per cent, young
2–septate, 4 per cent, 31 x 4.4
3–septate, 95 per cent, 34 x 4.5 (25–40 x 4.1–4.9)μ
4–septate, rare, 40 x 5.1 (only a few measured)

Average of the above measurements:

Conidia: 0–septate, rare to none
1–septate, 1.5 per cent, (usually immature)
2–septate, 4 per cent
3–septate, 93 per cent, 30.2 x 4.27μ
4–septate, 1.5 per cent, 36 x 4.75μ
5–septate, rare to none

IV. SECTION GIBBOSUM Wr., Phytopath. 3:31, fig. 1, L and M

Conidia with from hyperbolic or parabolic to elliptic dorsal curve, conspicuously broader in the middle, with more or less long, narrow apex, prominently pedicellate, mostly 5–septate; intercalary chlamydospores always present; color of substratum and conidial mass typically from pale buff to cinnamon and sepia; mycelium from hyaline to brown.

7. *Fusarium gibbosum* Ap. et Wr. (Figs. 1Y and 6)

Appel, O., and Wollenweber, H. W., Arb. K. biol. Anst. Land- u. Forstw. 8:185–190, text fig. 10, C and D. 1910. Wollenweber, H. W., Phytopath. 3:32, fig. 1, M. 1913.

Conidia often with hyperbolic dorsal curve, conspicuously broader in the middle, with long, narrow apex, prominently pedicellate, typically 5-septate, 41.6 x 4.6 (40–46 x 4.4–4.7)μ, sometimes also 0– to 7–septate, in minute nonconverging sporodochia or spreading over mycelium singly, from hyaline to light pinkish cinnamon in color; chlamydospores inter-

calary, always present; aërial mycelium typically present, short, fine, medium loose; colony faintly zonate; substratum on potato agar rich in glucose, from pale flesh to cinnamon in color.

Hab. On stems and tubers of *Solanum tuberosum* in Germany, rare.

The organism was not isolated by the writer, but a culture of it was carefully examined on several different media with the following results in regard to spore septation and size:

On slightly acidified hard potato agar, culture twenty-four days old:

Conidia: 3–septate, 5 per cent
4–septate, 15 per cent, 32–4.1μ
5–septate, 80 per cent, 43.2 x 4.6 (38–50 x 4.3–4.9)μ

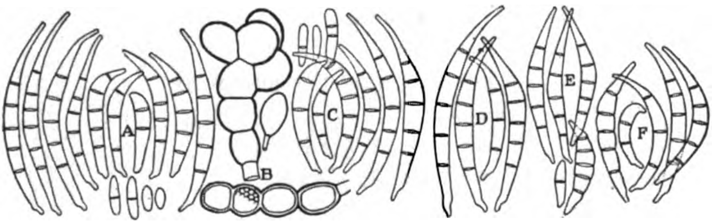

FIG. 6.—*Fusarium gibbosum.* A, *Pseudopionnotal conidia from 10-days-old culture on hard lima-bean agar;* B, *intercalary chlamydospores,* C, *conidia, from 71-days-old culture on red raspberry cane plug;* D, *pseudopionnotal conidia from 118-days-old culture on hard lima-bean agar with 2 per cent glucose;* E, *conidia from 42-days-old culture on potato stem plug;* F, *pseudopionnotal conidia from 24-days-old culture on slightly acidified hard potato agar*

On red raspberry cane plug, culture seventy-one days old:

Conidia: 3–septate, 5 per cent
4–septate, 5 per cent
5–septate, 90 per cent, 40 x 4.6 (33–46 x 4.2–5.2)μ
6–septate, rare

On hard lima-bean agar with 2 per cent glucose, culture one hundred and eighteen days old:

Conidia: 4–septate, 1 per cent
5–septate, 94 per cent, 37 x 4.6 (26–44 x 3.9–4.9)μ
6–septate, 3 per cent, 42 x 4.7μ
7–septate, 2 per cent

On hard lima-bean agar, culture ten days old:

Conidia: 0–septate, 1.5 per cent, 7.5 x 3.2 μ
1–septate, 4 per cent, 10 x 3.2 (7–17 x 2.7–3.5)μ
2–septate, very rare
3–septate, 4 per cent, 27 x 4.1 (19–41 x 3.5–4.1)μ
4–septate, 3 per cent
5–septate, 86 per cent, 46 x 4.4 (35–58 x 4–4.8)μ
6–septate, 1.5 per cent, 52 x 4.5 (50–60 x 4.3–4.8)μ

Average of the above measurements:

Conidia: 0–septate, 0.5 per cent, 7.5 x 3.2μ
1–septate, 1 per cent, 10 x 3.2μ
2–septate, very rare
3–septate, 4 per cent, 27 x 4.1μ
4–septate, 6 per cent, 27 x 4.1μ
5–septate, 87 per cent, 41.6 x 4.6μ
6– and 7–septate, 1.5 per cent, 47 x 4.6μ

The averages of Appel and Wollenweber's (1910:189–190) measurements are as follows:

Conidia: 3–septate, 3 per cent, 25 x 4.5μ
4–septate, 2 per cent, 29 x 4.5μ
5–septate, 59 per cent, 42 x 4.4μ
6–septate, 23 per cent, 49 x 4.6μ
7–septate, 13 per cent, 49 x 4.7μ

There is a notable difference between the data presented by the writer and those of Wollenweber only in the proportion of 6– and 7–septate conidia, the size of 5– and of 6– and 7–septate conidia being very much the same.

8. *Fusarium falcatum* Ap. et Wr. (Figs. 1x and 7)

Appel, O., and Wollenweber, H. W., Arb. K. biol. Anst. Land- u. Forstw. 8:175–185; Pl. II, figs. 100 to 110; Pl. III, fig. 9; text fig. 10, A. 1910.

Syn. *Fusarium vasinfectum* var. *Pisi* Schikorra, Arb. K. biol. Anst. Land- u. Forstw. 4:157, Pl. VII, 1906; not *F. vasinfectum* var. *Pisi* van Hall, Ber. deut. Bot. Gesell. 21:4, pl. 4, 1903. Wollenweber, Phytopath. 3:31, fig. 1, L, 1913.

Conidia often with parabolic dorsal curve, conspicuously broader in the middle, with long and narrow apex, prominently pedicellate, typically 5–septate, 49.1 x 4.6 (43–54.5 x 4.5–4.7)μ, often 3– to 7–septate, 0– to 2– and 8–septate very rare, in minute sporodochia more or less converging into pseudopionnotes, from buff-pink to cinnamon on hard potato agar rich in glucose; intercalary chlamydospores always present; aërial mycelium very poorly developed or not developed at all, leaving slimy layer exposed; substratum about the same color as the spores.

Hab. Often on *Pisum sativum*, seldom on underground part of stem of *Solanum tuberosum*, in Germany, and cause of fruit rot of *Solanum lycopersicum* in Germany and in the United States.

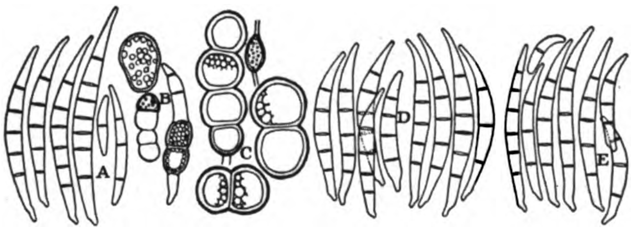

FIG. 7.—*Fusarium falcatum.* A, *Pseudopionnotal conidia,* B, *chlamydospores in mycelium and in spore, from 119-days-old culture on hard lima-bean agar with 2 per cent glucose;* C, *chlamydospores,* D, *pseudopionnotal conidia, from 71-days-old culture on red raspberry cane plug;* E, *pseudopionnotal conidia from 48-days-old culture on potato stem plug*

Differs from *F. gibbosum* mainly in having parabolic dorsal curve and typically exposed pseudopionnotes; also in considerably longer conidia.

The organism was not isolated by the writer, but the culture was obtained through the courtesy of Dr. Wollenweber. The writer's cultural observations in regard to septation and size of spores of this organism on various media are as follows:

On slightly acidified hard potato agar, culture twenty-four days old:

Conidia: 3–septate, 3 per cent, 28–42 x 3.5–4μ } (only a few measured)
4–septate, 9 per cent, 33–42 x 3.5–4μ }
5–septate, 77 per cent, 50 x 4.5 (43–58 x 4–5.3)μ
6–septate, 10 per cent, 54 x 5 (50–60 x 4.8–5.3)μ
7–septate, 1 per cent, about 60–70 x 4.8–5.3μ

On red raspberry cane plug, culture seventy-one days old:

Conidia: 3–septate, 2 per cent
4–septate, 3 per cent
5–septate, 90 per cent, 43 x 4.6 (36–49 x 4–5.2)μ
6–septate, 5 per cent, 46 x 4.8 (43–53 x 4.3–5.2)μ

On hard lima-bean agar with 2 per cent glucose, culture one hundred and nineteen days old:

Conidia: 1–septate, 2.5 per cent, 15 x 2.7μ (only two measured)
3–septate, 3 per cent, 30 x 3.6 (10–44 x 3–4.7)μ
4–septate, 5 per cent
5–septate, 81 per cent, 49 x 4.7 (42–55 x 4.3–5.2)μ
6–septate, 6 per cent, 51 x 4.9 (45–56 x 4.6–5.2)μ
7–septate, 2.5 per cent, 52 x 5.2 (47–58 x 5.2)μ
8–septate, exceptionally rare, 58 x 5.4 (only one measured)

On hard lima-bean agar, culture eleven days old:

Conidia: 0–septate, rare
2–septate, 2 per cent
3–septate, 30 per cent, 30 x 3.6 (20–40 x 3–4.3)μ
4–septate, 5 per cent
5–septate, 62 per cent, 54.5 x 4.5 (43–65 x 3.5–5.2)μ
6–septate, 1 per cent, 64 x 4.8 (59–70 x 4.6–5.3)μ
7–septate, rare, same as 6–septate

Average of the above measurements:

Conidia: 0–septate, very rare
1–septate, 0.5 per cent
2–septate, 0.5 per cent, 15 x 2.7μ
3–septate, 9.5 per cent, 30 x 3.6μ
4–septate, 5.5 per cent
5–septate, 77.5 per cent, 49.1 x 4.56μ
6–septate, 5.5 per cent, 54 x 4.9μ
7–septate, 1 per cent, 58 x 5.1μ
8–septate, very rare, 58 x 5.4μ

Averages of Appel and Wollenweber's (1910:184) measurements are as follows:

Conidia: 5–septate, 46 x 4.7μ
6–septate, 49 x 4.4μ

The measurements of the writer show some deviation from these, but the deviation is small and can be explained entirely by the fact that the writer's measurements were taken from much younger cultures, which usually yield somewhat longer conidia than those produced in old cultures.

9. *Fusarium falcatum* Ap. et Wr. var. **fuscum** n. var. (Fig. 8; Pl. VII, fig. 8)

Conidia with from ellipsoidal to parabolic dorsal curve, conspicuously broader in the middle, prominently pedicellate, typically 5–septate,

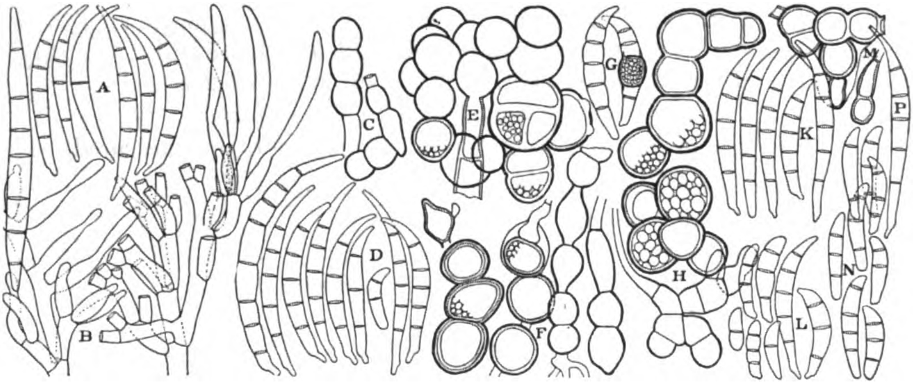

FIG. 8.—*Fusarium falcatum var. fuscum.* A, *Pseudopionnotal conidia,* B, *conidiophores, from 4-days-old culture on hard potato agar;* C, *intercalary chlamydospores,* D, *pseudopionnotal conidia, from 10-days-old culture on hard bean agar;* E, *cluster of intercalary chlamydospores from 99-days-old culture on potato tuber plug;* F, *intercalary chlamydospores in long chains,* G, *conidia with and without chlamydospores, from 176-days-old culture on corn agar;* H, *young and old chlamydospores,* K, *sporodochial,* L, *aërial, conidia, from 79-days-old culture on red raspberry cane plug;* M, *intercalary and terminal chlamydospores,* N, *aërial conidia, from 50-days-old culture on rye straw;* P, *typical conidium from a large sporodochium of 29-days-old culture on hard oat agar*

45 x 4.6 (40–51 x 4.4–4.7)μ, 3– and 4–septate ones also present, 6– and 7–septate rare, 8–septate very rare, typically in conspicuous plectenchymic or aplectenchymic sporodochia, from light buff and honey yellow to buckthorn and cacao brown, on potato agar rich in glucose; chlamydospores intercalary, always present, sometimes by their abundance and color making the entire medium and the aërial mycelium of a dark brown color; aërial mycelium always present, high, from fine to medium fine, more or less loose, hyaline at first, later becoming from tawny olive to brown; color of substratum on agars from hyaline to that of the spores.

Hab. On rotted tubers of *Solanum tuberosum*, New York State.

Differs from *F. falcatum* mainly by large sporodochia, more profuse chlamydospore production, well-developed aërial mycelium, and typical absence of pseudopionnotes.

The organism was isolated only once, from a potato tuber slightly rotted near the stem end, which was received from a potato grower in New York. The measurements of conidia on different media are as follows:

On slightly acidified hard potato agar, culture four days old:

Conidia: 0– and 1–septate, few, very young
3–septate, 4 per cent, 38 x 4.3 (35–42 x 4.1–4.7)μ
4–septate, 6 per cent, 41.6 x 4.4 (35–44 x 4.1–4.7)μ
5–septate, 88 per cent, 45.5 x 4.6 (40–49 x 4.1–4.8)μ
6– and 7–septate, 2 per cent, 50–80 x 5.5μ (only a few measured)
The largest 5–septate conidium observed measured 67 x 5.8μ

On red raspberry cane plug, culture seventy-nine days old:

Conidia: 3–septate, 1 per cent
4–septate, 4 per cent
5–septate, 95 per cent, 40 x 4.7 (31–48 x 4.3–5.2)μ

On hard lima-bean agar, culture ten days old:

Conidia: 3–septate, 3 per cent, 34 x 4.4 (19–40 x 3.1–4.7)μ
4–septate, 6 per cent
5–septate, 91 per cent, 45 x 4.4 (36–61 x 4–4.8)μ

On hard oat agar, culture twenty-nine days old, from a sporodochium about 3 millimeters in diameter:

Conidia: 3–septate, 2 per cent
4–septate, 5 per cent
5–septate, 93 per cent, 51 x 4.6 (45–53 x 4.1–4.9)μ

Average of the above measurements:

Conidia: 3–septate, 2.5 per cent, 36 x 4.3μ
4–septate, 5 per cent, 41.6 x 4.4μ
5–septate, 92 per cent, 45 x 4.6μ
6– and 7–septate, 0.5 per cent

10. *Fusarium caudatum* Wr. var. **Solani** n. var. (Figs. 1z and 9; Pl. IV, fig. 7; Pl. VI, fig. 3)

Conidia with from parabolic to ellipsoid dorsal curve, conspicuously broader at the middle, with very long, narrow, whiplike apex, prominently pedicellate, typically 5– to 7–septate; measuring on the average, 5–septate, 48 x 4.6 (40–55 x 4.3–4.7)μ, 7–septate, 64.7 x 4.6 (57–69 x 4.4–4.8)μ; rarely in pseudopionnotes, typically in small aplectenchymic sporodochia, tinted from cream-buff to cinnamon, clay, and Saccardo's amber in a

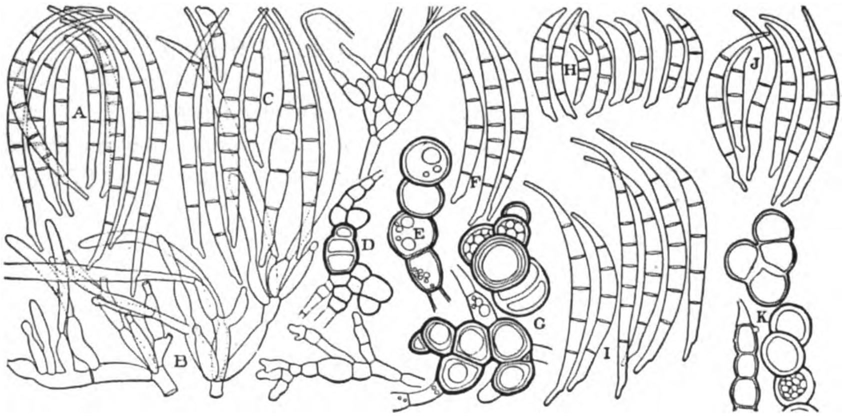

FIG. 9.—*Fusarium caudatum var. Solani.* A, *Pseudopionnotal conidia,* B, *conidiophores, from 9-days-old culture on slightly acidified hard potato agar;* C, *pseudopionnotal conidia from 38-days-old culture on potato stem plug;* D *and* E, *chlamydospores from 50-days-old culture on red raspberry cane plug (magnification 250 times);* F, *conidia from aërial sporodochium of 118-days-old culture on hard lima-bean agar with 2 per cent glucose;* G, *cluster of chlamydospores,* H, *aërial conidia, from 50-days-old culture on rye straw;* I, *sporodochial conidia in oozing drop of liquid from 9-days-old culture on hard lima-bean agar;* J, *aërial conidia,* K, *intercalary chlamydospores, from 69-days-old culture on red raspberry cane plug*

plate culture on a potato hard agar rich in glucose; chlamydospores intercalary, always present in greater or less abundance; aërial mycelium very well developed, high, uniform, medium dense, from hyaline when young to sepia in old cultures, mostly from brownish to dresden brown; substratum, on potato agar rich in glucose, from pinkish buff when young to ochraceous tawny and snuff brown shaded to sepia in very old cultures.

Hab. On superficial dry-rot spots on tubers of *Solanum tuberosum,* Atlanta, New York.

Differs from *F. caudatum* Wr. (see Wollenweber 1914:262–263, Pl. XVI, fig. M) mainly by broader conidia, which in the latter organism average only from 3 to 4.5μ in diameter.

The organism was twice isolated, in 1912 and in 1913, from superficial dry rot of potato tubers collected at Atlanta, New York. The measurements of conidia on different media are as follows:

On red raspberry cane plug, culture sixty-nine days old:
Conidia: 3–septate, 10 per cent, 30 x 4 (26–35 x 3.5–4.5)μ
4–septate, 5 per cent, 34 x 4.4 (32–40 x 4–4.8)μ
5–septate, 85 per cent, 40 x 4.8 (33–55 x 4–5.4)μ

On slightly acidified hard potato agar, culture nine days old:
Conidia: 3–septate, 1 per cent, about 38 x 4μ (only a few measured)
4–septate, 8 per cent, about 40 x 4.2μ (only a few measured)
5–septate, 43 per cent, 55 x 4.3 (38–69 x 3.5–5.9)μ
6–septate, 27 per cent, 65 x 4.4 (55–84 x 4.1–5.3)μ
7–septate, 21 per cent, 69 x 4.4 (60–85 x 4.1–5.9)μ
8–septate, very rare

On hard lima-bean agar with 2 per cent glucose, culture one hundred and eighteen days old:
Conidia: 4–septate, 1 per cent
5–septate, 29 per cent, 46 x 4.7 (43–59 x 4.3–5.2)μ
6–septate, 32 per cent, 53 x 4.8 (48–60 x 4.3–5)μ
7–septate, 37 per cent, 57 x 4.8 (50–62 x 4.7–5)μ
8–septate, 1 per cent, 61 x 5μ (only one measured)

On hard lima-bean agar, culture nine days old:
Conidia: 5–septate, 55 per cent, 52 x 4.5 (45–61 x 4–4.8)μ
6–septate, 35 per cent, 65 x 4.7 (55–71 x 4.3–4.8)μ
7–septate, 10 per cent, 68 x 4.7 (58–78 x 4.3–4.8)μ

Average of the above measurements:
Conidia: 3–septate, 3 per cent, 34 x 4μ
4–septate, 3.5 per cent, 37 x 4μ
5–septate, 53 per cent, 48 x 4.6μ
6–septate, 23.5 per cent, 58 x 4.6μ
7–septate, 17 per cent, 64.7 x 4.6μ
8–septate, rare, 61 x 5μ (only one measured)

V. SECTION ROSEUM Wr. (emended), Phytopath. 3:32, fig. 1 N, 1913

Conidia broad ellipsoid, typically of an even diameter for a considerable part of their length, comparatively narrow (from 3.6 to 4.3μ in average diameter), always very gradually attenuate toward both ends, conidia of all fruiting forms of the same shape and type; true chlamydospores always absent; on agars rich in glucose, from honey yellow and morocco red to Eugenia red, sometimes nearly hyaline.

11. *Fusarium acuminatum* Ell. et Ev. emend. Wr.

Cf. Wollenweber, H. W., Journ. Agr. Research 2:269–270, Pl. XVI, fig. G. 1914. *Fusarium acuminatum* Ell. et Ev., Proc. Acad. Sci. Phila. 1895:441. Saccardo, Syll. Fung. 14:1125–1126. 1899. Wollenweber's diagnosis (page 269 of reference cited) is as follows:

"Conidia, scattered, in sporodochia or in pionnotes, orange in mass. Conidia average as follows: 5-septate, 40 to 70 by 3 to 4.5μ; 4-septate (less common), 30 to 60 by 3 to 4.5μ; 3-septate, 20 to 45 by 2.75 to 4.25μ. Conidia of 0–, 1–, 2–, 6–, and 7–septations are occasionally found. Subnormal small conidia may be mistaken for conidia of the section Discolor, but normal sporodochia develop on repeatedly whorl-like branched conidiophores, giving the characteristic conidia of the section Roseum. The conidia show in side view hyperbolic or parabolic curves, in contrast to *Fusarium metacroum* App. and Wollenw., the conidia of which are as a rule more nearly straight. Blue globose sclerotia, 50–70μ thick, occur and form a striking contrast to the carmine plectenchymatic thallus on starchy media, such as steamed potato tubers. Both blue and carmine are basic modifications of the fungus, while yellow (on rice) is the acid one, turning blue to purple violet with the addition of an alkali.

"Habitat. Occurs on partly decayed plants, especially on stems, roots, and tubers, also on fruits. Found on Solanum, Ipomoea, Fagus (beech nuts), and *Impatiens balsamina* in the United States of America."

Ellis and Everhart's description is incomplete, but Wollenweber says (on page 270 of reference cited) that he "found this fungus so widely distributed on potato stems in the New England States that he feels justified in identifying it as *Fusarium acuminatum*." The writer did not study this fungus.

12. ***Fusarium metacroum*** Ap. et Wr. (Fig. 10; Pl. VII. fig. 5)

Appel, O., and Wollenweber, H. W., Arb. K. biol. Anst. Land- u. Forstw. 8:132–141; Pl. I, figs. 111 to 118; Pl. III, fig. 8. 1910.

Conidia broad, ellipsoid, more or less pointed at apex, seldom prominently pedicellate, typically 5–septate, 53 x 4.1 (43–65 x 3.8–4.3)μ, often 3– or 4–septate, seldom 0– to 2–, rarely 6–, exceptionally up to 12–septate, in minute, more or less converging, sporodochia forming exposed pseudopionnotes, from corinthian red to clay color, typically from dragon's-

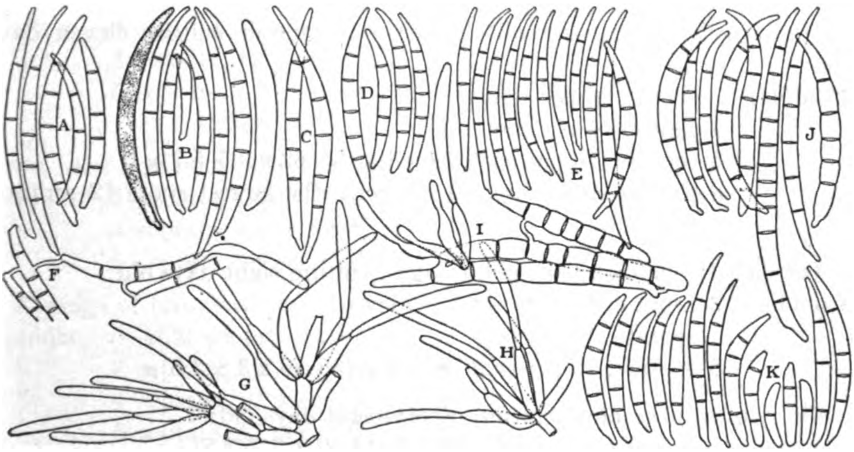

FIG. 10.— *Fusarium metacroum. Pseudopionnotal conidia:* A, *from 65-days-old culture on rye grain;* B, *from 10-days-old culture on hard lima-bean agar;* C, *from 8-days-old culture on hard lima-bean agar with 2 per cent glucose;* D, *from 113-days-old culture on potato stem plug;* E *and* F, *from 23-days-old culture on red raspberry cane plug;* I *and* J, *from 11-days-old culture on slightly acidified hard potato agar;* K, *from 66-days-old culture on rye grain.* G *and* H, *Conidiophores from 23-days-old culture on red raspberry cane plug*

blood red to brick red; chlamydospores absent; aërial mycelium typically absent; substratum from madder brown and brazil red to russet color; conidia often densely granulate with indistinct septation.

Hab. On grains of *Triticum vulgaris* in Germany and on rotted tubers of *Solanum tuberosum* in New York State.

The organism was isolated, together with *F. diversisporum*, from a rotted tuber from Long Island. The two fungi were growing together, and in the original culture the mixture appeared to be a pink Fusarium. The fungi were separated by dilution and remained very distinct from each

other. *F. metacroum* isolated by the writer is in all respects identical with the originally described organism.

The measurements of the conidia from the original culture when grown on various media are as follows:

On red raspberry cane plug, culture twenty-three days old:
Conidia: 3–septate, 42 per cent, 46 x 3.2 (35–56 x 2.6–4.1)μ
4–septate, 28 per cent, 50 x 3.5 (40–62 x 2.9–4.1)μ
5–septate, 30 per cent, 50 x 3.8 (45–63 x 3.3–4.3)μ

On hard lima-bean agar with 2 per cent glucose, culture eleven days old:
Conidia: 3–septate, 8 per cent
4–septate, 7 per cent
5–septate, 75 per cent, 54 x 4.1 (35–62 x 3.5–5.7)μ
6–septate and more, 10 per cent, the largest spore 12–septate, 91 x 5.3μ

On slightly acidified hard potato agar, culture eight days old:
Conidia: 3–septate, 15 per cent
4–septate, 15 per cent
5–septate, 70 per cent, 65 x 4.2 (55–73 x 3.8–4.8)μ

On potato tuber plug, culture ninety-eight days old:
Conidia: 1–septate, 5 per cent, 19 x 3 (14–21 x 2.7–3.5)μ
2–septate, few
3–septate, 10 per cent, 36 x 3.8 (28–43 x 3.5–4.2)μ
4–septate, 30 per cent, 46 x 3.9 (36–51 x 3.5–4.7)μ
5–septate, 55 per cent, 50 x 4 (42–63 x 3.5–4.4)μ

On potato stem plug, culture one hundred and thirteen days old:
Conidia: 3–septate, 25 per cent, 36 x 3.7 (33–39 x 3.4–3.9)μ
4–septate, 20 per cent, about 39 x 4μ (only a few measured)
5–septate, 55 per cent, 43 x 4 (38–47 x 3.5–4.2)μ, the longest 5–septate, 63 x 3.85μ

On whole steamed potato tuber, culture thirty-eight days old:
Conidia: 3–septate, 40 per cent, 42 x 3.9 (37–53 x 3.5–4.1)μ
4–septate, 35 per cent, 45 x 4.1μ
5–septate, 25 per cent, 54 x 4.3 (47–63 x 3.7–4.8)μ

On rye grain, culture sixty-five days old:

(1) From a slimy heap of conidia 1 millimeter in diameter

Conidia: 3–septate, 27 per cent, 43 x 3.8 (31–49 x 2.9–4.7)μ
4–septate, 11 per cent, 44 x 4.1 (40–63 x 2.6–4.8)μ
5–septate, 62 per cent, 54.5 x 4.1 (43–67 x 3–5.2)μ

(2) From a minute, semi-dry fleck of conidia, culture sixty-six days old

Conidia: 0–septate, 2 per cent
1–septate, 3 per cent, 20 x 3.5 } (only a few measured)
2–septate, 3 per cent, 23 x 3.9 }
3–septate, 65 per cent, 32 x 3.9 (22–47 x 3.5–4.4)μ
4–septate, 12 per cent, 43 x 4.1 (38–48 x 3.5–4.4)μ
5–septate, 15 per cent, 45 x 4.3 (38–48 x 3.5–4.7)μ, the largest 53 x 5.25μ

On hard lima-bean agar, culture ten days old:

Conidia: 3–septate, 6 per cent, 48 x 3.7μ (only three measured)
4–septate, 4 per cent
5–septate, 90 per cent, 61 x 3.9 (43–68 x 3.5–4.1)μ

Average of the above measurements:

Conidia: 0– to 2–septate, rare
3–septate, 26 per cent, 40.4 x 3.7μ
4–septate, 19 per cent
5–septate, 54 per cent, 53 x 4.1μ
6– and 7–septate, 1 per cent

The averages of Appel and Wollenweber's measurements are as follows:

Conidia: 3–septate, 9 per cent, 39 x 3.9μ
4–septate, 14 per cent, 43 x 4.2μ
5–septate, 76 per cent, 53 x 4.3μ
6–septate, 1 per cent, 63 x 4.6μ

13. *Fusarium metacroum* Ap. et Wr. var. **minus** n. var. (Fig. 11)

Conidial type as in *F. metacroum*, 5–septate conidia 54 x 3.6 (46–60 x 3.4–3.9)μ.

Hab. On stem of *Solanum tuberosum*, New York State.

Differs from *F. metacroum* by narrower conidia, often distinct plectenchymic substratum, and swellings in hyphæ very similar to true chlamydospores.

The organism was isolated only once, from a half-dead stem of potato plant at Atlanta, New York, from a pseudopionnotal spore mass. The measurements of the conidia produced by the organism on various media are as follows:

On red raspberry cane plug, culture thirty-one days old:
Conidia: 1–septate, 0.5 per cent, 20 x 2.5μ
2–septate, very few
3–septate, 46.5 per cent, 43 x 2.8 (23–53 x 2.3–3.5)μ
4–septate, 31 per cent, 48 x 3.2 (40–60 x 2.3–3.5)μ
5–septate, 22 per cent, 52 x 3.4 (42–60 x 2.9–4)μ
6–septate, rare, 61 x 3.4μ (only one measured)

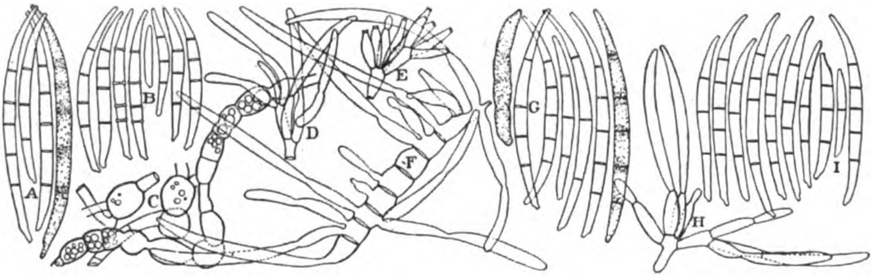

FIG. 11.—*Fusarium metacroum var. minus.* A, *Conidia from 18-days-old culture on hard lima-bean agar;* B, *conidia from the original specimen, potato stem, August 7, 1912;* C, *chlamydo-spore-like structures of hyphæ from 26- and 176-days-old cultures on corn agar;* D, *conidiophore from the original specimen, potato stem, August 7, 1912;* E, *conidiophores from 31-days-old culture on red raspberry cane plug;* F, *conidia producing numerous conidiophores from 10-days-old culture on hard lima-bean agar;* G, *normal conidia from 10-days-old culture on hard lima-bean agar;* H, *conidiophores from 31-days-old culture on red raspberry cane plug;* I, *conidia from 31-days-old culture on red raspberry cane plug. All conidia are from pseudopionnotes*

On hard lima-bean agar with 2 per cent glucose, culture eight days old:
Conidia: 3–septate, 17 per cent
4–septate, 17 per cent
5–septate, 66 per cent, 60 x 3.6 (53–65 x 3–4.2)μ

On potato tuber agar, culture ninety-eight days old:
Conidia: 0–septate, 5 per cent
1–septate, 5 per cent
2–septate, rare
3–septate, 20 per cent, 34 x 3.5 (26–39 x 3–4)μ
4–septate, 30 per cent, 42 x 3.8 (36–48 x 3.5–4.1)μ
5–septate, 40 per cent, 46 x 3.9 (40–54 x 3.5–4.1)μ.

On rye grain, culture sixty-five days old:
Conidia: 3–septate, 20 per cent, 41 x 3.2 (36–46 x 2.9–4)μ
4–septate, 17 per cent, 48 x 3.3 (40–54 x 2.9–4)μ
5–septate, 63 per cent, 52 x 3.7 (40–60 x 3–4.1)μ

On hard lima-bean agar, culture ten days old:
Conidia: 1–septate, very few
3–septate, 11 per cent, 50 x 3.3 (29–61 x 3–3.7)μ
4–septate, 4 per cent
5–septate, 85 per cent, 60 x 3.5 (45–67 x 3.1–4)μ

Average of the above measurements:
Conidia: 0– to 2–septate, 2 per cent, 20 x 2.5μ
3–septate, 23 per cent, 42 x 3.2μ
4–septate, 20 per cent
5–septate, 55 per cent, 54 x 3.6μ
6–septate, very rare, 61 x 3.4μ

14. ***Fusarium subulatum*** Ap. et Wr. (Fig. 1w; Fig. 12, G to J; Pl. II, fig. 11; Pl. VII, fig. 4)

Appel, O., and Wollenweber, H. W., Arb. K. biol. Anst. Land- u. Forstw. 8:118–132, Pl. II, figs. 65 to 87. 1910. Wollenweber, H. W., Phytopath. 3:32, fig. 1N. 1913.

Conidia slightly elliptically curved, typically of nearly even diameter for the greater part of their length, very gradually attenuate toward both ends, slightly pedicellate, typically 5–septate, 58 x 3.64 (48–65 x 3.4–3.85)μ, usually in numerous, sometimes converging sporodochia ($\frac{1}{4}$ to 1 millimeter in diameter), produced near substratum and lower aërial mycelium, from pink-flesh to apricot-buff and from coral red to brick red in color, with darker shades in old moist cultures; chlamydospores absent; aërial mycelium typically present, at first hyaline, then testaceous color and other hues of red; on various agars from vinaceous tawny and madder brown to pomegranate purple and Eugenia red.

Hab. A cosmopolitan saprophyte, of very wide occurrence on dead substrata, in soil and water, also parasitic on cereals and on tubers of *Solanum tuberosum*.

The organism was twice isolated by the writer from rotted potato tubers, and the strains were compared with a culture of the originally described organism obtained through the courtesy of Dr. Wollenweber

and proved to be identical. The writer's measurements of conidia of the original strain are as follows:

On red raspberry cane plug, culture twenty-seven days old:
Conidia: 3–septate, 10 per cent, 55 x 2.9μ
4–septate, 20 per cent, 60.4 x 3 (54–76 x 2.6–3.5)μ
5–septate, 70 per cent, 65 x 3.4 (57–76 x 2.6–4.1)μ

On potato tuber plug, culture ninety-nine days old:
Conidia: 0– to 2–septate, none to very few
3–septate, 35 per cent, 33 x 3.7 (27–40 x 3–4)μ
4–septate, 20 per cent, 38 x 3.7 (32–42 x 3–4.1)μ
5–septate, 45 per cent, 48 x 3.85 (42–58 x 3.5–4.1)μ
6–septate, rare, 57 x 4μ (only one measured)

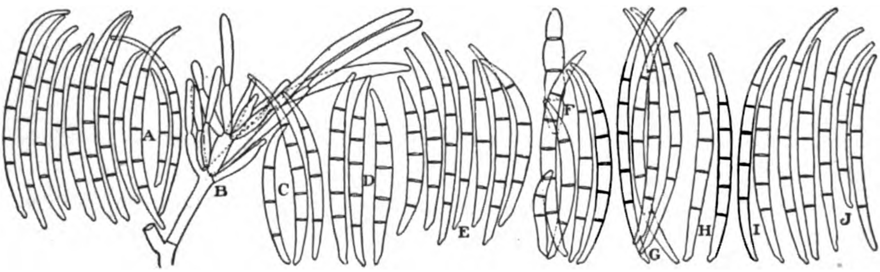

FIG. 12.— A-F, *Fusarium subulatum var. brevius:* A, *Conidia,* B, *conidiophore, from small sporodochium of 31-days-old culture on red raspberry cane plug;* C, *sporodochial conidia from 113-days-old culture on potato stem plug;* D, *pseudopionnotal conidia from 38-days-old culture on whole steamed potato tuber;* E, *sporodochial conidia from 65-days-old culture on rye straw;* F, *aërial conidia from 10-days-old culture on hard lima-bean agar.*
G-J, *F. subulatum:* G, *Sporodochial conidia from 31-days-old culture on red raspberry cane plug;* H, *semi-dry conidia from sporodochium of 38-days-old culture on steamed potato tuber;* I, *sporodochial conidia from 113-days-old culture on potato stem plug;* J, *sporodochial conidia from 65-days-old culture on rye grain*

On potato stem plug, culture one hundred and thirteen days old:
Conidia: 3–septate, 5 per cent, about 35 x 3μ (only a few measured)
4–septate, 4 per cent
5–septate, 91 per cent, 54 x 3.6 (47–65 x 3.2–3.9)μ

On steamed potato tuber, culture thirty-eight days old:
Conidia: 3–septate, 3 per cent, about 40 x 3.5μ
4–septate, 8 per cent, about 48 x 3.6μ
5–septate, 89 per cent, 55 x 3.7 (37–63 x 3.5–3.9)μ
6–septate, few, same measurement as 5–septate

On rye grain, culture sixty-five days old:

Conidia: 3–septate, 4 per cent, 52 x 3.4 (42–55 x 2.9–4)μ
4–septate, 15 per cent, 54 x 3.5 (42–67 x 2.9–4.1)μ
5–septate, 81 per cent, 64 x 3.7 (45–75 x 2.9–4.2)μ

On hard lima-bean agar, culture ten days old:

Conidia: 0–septate, rare
2–septate, very rare
3–septate, 11 per cent, 45 x 3.1 (33–60 x 3–3.5)μ
4–septate, 19 per cent
5–septate, 70 per cent, 60 x 3.6 (53–67 x 3.1–4)μ
9–septate, rare, 69 x 5.7μ (only one measured)

Average of the above measurements:

Conidia: 0–septate, none to rare
1– and 2–septate, none to rare
3–septate, 11 per cent, 43.3 x 3.3μ
4–septate, 15 per cent
5–septate, 74 per cent, 58 x 3.64μ
6– to 9–septate, none to rare

The averages of Appel and Wollenweber's measurements for the same organism are as follows:

Conidia: 1–septate, rare
$\left.\begin{array}{l}\text{3–septate}\\\text{4–septate}\end{array}\right\}$ 28 per cent $\left\{\begin{array}{l}36.5 \times 3.86\mu\\51.5 \times 3.5\mu\end{array}\right.$
5–septate, 62 per cent, 61 x 3.86μ
6–septate, 9 per cent, 69 x 4μ
7–septate, 1 per cent

This shows the 5–septate conidia to be in about the same proportion and of about the same size as found by the writer.

15. *Fusarium subulatum* Ap. et Wr. var. **brevius** n. var. (Fig. 12, A to F; Pl. II, fig. 12; Pl. VII, fig. 3)

Conidia and fruiting forms of the same type as those of *F. subulatum;* chlamydospores also absent; 5–septate conidia average 50 x 3.8 (41–58 x 3.1–4.2)μ in size.

Hab. On rotted tuber of *Solanum tuberosum*, Ithaca, New York.

Differs from *F. subulatum* Ap. et Wr. mainly in shorter conidia, absence of carmine color in substratum, and high, better-developed, aërial mycelium.[39]

The measurements of the conidia on various media are as follows:

On red raspberry cane plug, culture thirty-one days old:

Conidia: 3–septate, 35 per cent, 40 x 2.7 (29–49 x 2.3–3.3)μ
4–septate, 20 per cent, 51 x 3 (45–53 x 2.3–3.4)μ
5–septate, 45 per cent, 55 x 3.1 (48–60 x 2.9–3.8)μ

On potato tuber plug, culture ninety-nine days old (in general, spores more or less deteriorated):

Conidia: 1–septate, 1 per cent
3–septate, 33 per cent, 30 x 3.6 (21–42 x 3–4)μ
4–septate, 20 per cent, 36 x 3.9 (33–42 x 3.5–4.1)μ
5–septate, 46 per cent, 41 x 4 (35–48 x 3.5–4.1)μ
6–septate, rare, 43 x 4.1μ (only one measured)

On potato stem plug, culture one hundred and thirteen days old:

Conidia: 3–septate, 67 per cent, 34 x 3 (28–49 x 2.9–3.6)μ
4–septate, 20 per cent, 42 x 3.3 (37–48 x 3–3.8)μ
5–septate, 13 per cent, 44.6 x 3.4 (38–47 x 3–3.8)μ

On whole steamed potato tuber, culture thirty-eight days old:

Conidia: 3–septate, 25 per cent, 37 x 3.8 (31–42 x 3.5–4)μ
4–septate, 35 per cent, 43 x 4 (36–49 x 3.5–9.2)μ
5–septate, 40 per cent, 47 x 4.1 (40–56 x 3.5–4.4)μ
6–septate, few, 52 x 4.4 (only a few measured)

On rye grain, culture sixty-five days old:

Conidia: 3–septate, 16 per cent, 42 x 4 (36–49 x 3.5–4.3)μ
4–septate, 17 per cent, 45 x 4.1 (36–54 x 3.5–4.3)μ
5–septate, 67 per cent, 51 x 4.2 (43–58 x 3.7–4.7)μ

On hard lima-bean agar, culture ten days old:

Conidia: 0–septate, very rare
1–septate, very rare
2–septate, very rare
3–septate, 24 per cent, 41 x 3.3 (36–48 x 3–3.5)μ
4–septate, 20 per cent
5–septate, 56 per cent, 52 x 3.9 (42–59 x 3.2–4.1)μ

[39] This grows straight up and out from the point of inoculation in a plate culture on potato agar in the first week of its growth, while the aërial mycelium in *F. subulatum* is always of a more or less loose, feltlike character, uniformly medium short over the surface of the colony.

On medium potato agar, culture ten days old:
Conidia: 3–septate, 9 per cent, about 45 x 3.3 (only two measured)
4–septate, 3 per cent
5–septate, 88 per cent, 58 x 3.5 (47–64 x 3.1–4)μ

Average of the above measurements:
Conidia: 0– to 2–septate, absent or more or less rare
3–septate, 30 per cent, 38.4 x 3.4μ
4–septate, 19 per cent
5–septate, 51 per cent, 49.8 x 3.76μ
6–septate, absent to 1 per cent, 47.5 x 4.25μ

16. **Fusarium effusum** n. sp. (Fig. 13; Pl. VII, fig. 6)

Conidia gradually pointed toward apex, distinctly but not prominently pedicellate, typically 5–septate, 50 x 4.3 (44.5–57 x 3.9–4.5)μ, often 3– to 7–, seldom 1– to 2–septate; single or in indistinct pseudopionnotes and in large (on oats, wheat, and the like, about ½ centimeter in diameter) plectenchymic sporodochia; shape of conidia of nearly the same type, in all stages and in mass, of salmon color and its tints; aërial mycelium typically well developed, though on an agar may be resupinate, uniform, without any differentiated tufts or strands, from white to cream and tints of salmon color; substratum, on glucose agar, from chamois to morocco red, and on glucose-free agar, from colorless to Eugenia red; typical spore germination by straight, unbranched tubes (Fig. 13 J); mycelium in young colony (Fig. 13 H) typically composed of nearly straight, sparse in number, and more or less regular, branches.

Hab. On dry tubers of *Solanum tuberosum*, Minnesota.

Latin description.—Conidiis gradatim in apicem acutis, distincte sed non insignite pedicellatis, typice 5–septatis, 50 x 4.3 (44.5–57 x 3.9–4.5)μ, saepe 3–7–, raro 1–2–septatis; continuis vel in indistinctis pseudopionnotibus atque in magnis (in avena, tritico, etc., circa ½ cm. diam.) plectenchymicis sporodochiis; conidiis prope eodem in omnibus gradibus typo, in totum "salmon-color" (R); aerio mycelio typice plene maturo, sed in agare interdum resupinato, uniformi, sine ullis discretis cristis aut fibris, ex albo "cream color" (R) "salmon color" (R) vel simili colore; substrato in agare glucoso e "chamois" (R) "morocco red" (R), in agare non glucoso ex hyalino "Eugenia red" (R); sporis per rectos et non ramosos cylindros typice germinatis (Fig. 13 J); mycelio in colonia juveni ex prope rectis, sparsis, plus minusve regularibus ramis composito.

Hab. In tuberibus aridis Solani tuberosi, Minnesota, Amer. bor.

The fungus was isolated in association with *F. Solani* from an old rotted potato tuber from Minnesota. Measurements of conidia from cultures on different media are as follows:

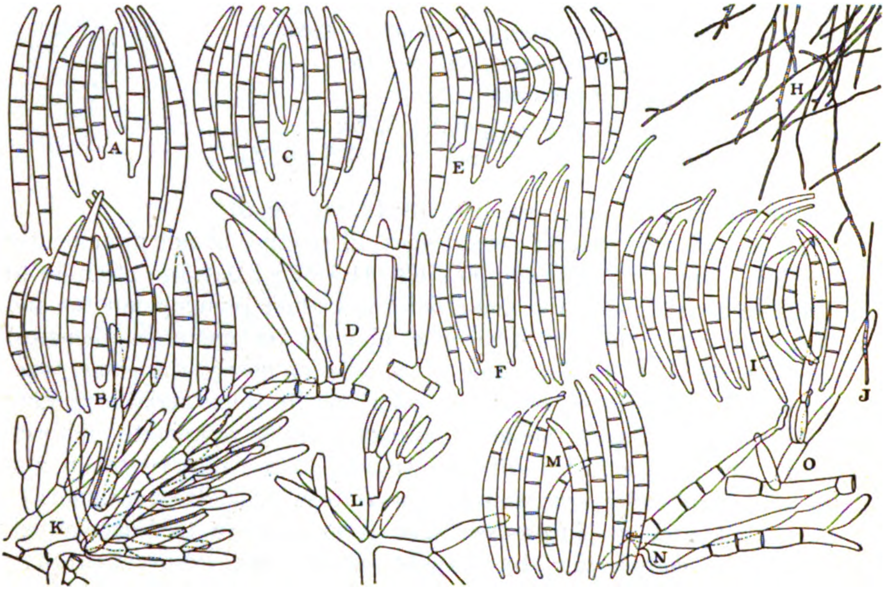

FIG. 13.—*Fusarium effusum.* A, *Pseudopionnotal conidia from 7-days-old culture on hard lima-bean agar with 2 per cent glucose;* B, *pseudopionnotal conidia from 13-days-old culture on hard lima-bean agar (rare forms of conidia shown at the center);* C, *pseudopionnotal conidia,* D, *conidiophores, from 9-days-old culture on medium potato agar;* E, *sporodochial conidia from 24-days-old culture on potato tuber plug;* F, *sporodochial conidia from 76-days-old culture on red raspberry cane plug;* G, *typical sporodochial conidia from 107-days-old culture on potato stem plug;* H, *character of colony growth (magnification 80 times),* I, *sporodochial conidia, from 34-days-old culture on rye grain;* J, *character of spore germination from potato-decoction hanging drop in van Tieghem cell (magnification 80 times);* K, L, *conidiophores,* M, *normal conidia,* N, *anastomosed conidia,* O, *conidiophores, from 36-days-old culture on corn meal*

On slightly acidified hard potato agar, culture ten days old; conidia from pseudopionnotes:

Conidia: 2–septate, rare
3–septate, 50 per cent, 34 x 4.1 (28–47 x 3–4.7)μ
4–septate, 10 per cent, 45 x 4.2μ
5–septate, 40 per cent, 50 x 4.5 (42–65 x 3.5–5.3)μ

On red raspberry cane plug, culture seventy-six days old; conidia from a sporodochium:

Conidia: 3–septate, 35 per cent, 42 x 3.3 (32–48 x 2.7–4)μ
4–septate, 15 per cent, 47 x 3.6 (42–53 x 3.2–4.3)μ
5–septate, 50 per cent, 49 x 3.9 (38–58 x 3.2–4.4)μ
6–septate, very rare

On hard lima-bean agar, 2 per cent glucose, culture seven days old; conidia from mycelium:

Conidia: 1–septate, 1 per cent
2–septate, 5 per cent
3–septate, 19 per cent, 39 x 4.2 (28–50 x 3.9–4.8)μ
4–septate, 10 per cent
5–septate, 60 per cent, 57 x 4.3 (52–72 x 4–5.3)μ
6–septate, 5 per cent, 62 x 4.7 (49–72 x 4.3–5.3)μ
7–septate, rare, 72 x 4.3μ (only one measured)
8–septate, exceptional, 87.5 x 5.8μ (only one measured)

On potato tuber plug, culture twenty-four days old; conidia from a sporodochium:

Conidia: 0–septate
1–septate, 2 per cent
2–septate, 1 per cent
3–septate, 12 per cent, 32 x 4.3 (28–36 x 3.9–4.4)μ
4–septate, 21 per cent, 34 x 4.5 (29–41 x 4.1–4.7)μ
5–septate, 61 per cent, 44.5 x 4.5 (35–51 x 4.1–4.8)μ
6– and 7–septate, 3 per cent, 53 x 4.7 (49–54 x 4.3–5.2)μ

On potato stem plug, culture one hundred and seven days old; conidia from a sporodochial mass (spores mostly with deteriorated ends):

Conidia: 3–septate, 5 per cent
4–septate, 15 per cent
5–septate, 80 per cent, 49 x 4 (35–63 x 3.5–4.7)μ

On hard lima-bean agar, culture ten days old; conidia from aërial mycelium:

Conidia: 1–septate, rare, 21 x 3.1μ (only one measured)
3–septate, 11 per cent, 36.2 x 4 (28–42 x 3.1–4.8)μ

4–septate, 4 per cent
5–septate, 81 per cent, 50.5 x 4.5 (38–60 x 3.9–4.8)μ
6–septate, 4 per cent, 56 x 4.7 (48–64 x 4.4–5.2)μ
7–septate, rare, 62 x 5.2μ (only one measured).

On the same medium as above, culture sixteen days old; conidia from aërial mycelium and indistinct pseudopionnotes:

Conidia: 1–septate, 1 per cent, 18 x 3.5μ (only a few measured)
2–septate, 1 per cent, 24 x 4μ (only a few measured)
3–septate, 12 per cent, 33 x 4 (21–44 x 2.9–4.8)μ
4–septate, 6 per cent
5–septate, 71 per cent, 50 x 4.3 (38–62 x 3.5–4.7)μ
6–septate, 7 per cent, 60 x 4.7 (55–64 x 4.5–4.8)μ
7–septate, 2 per cent, 62 x 4.7 (59–65 x 4.4–4.8)μ

Average of the above measurements:

Conidia: 1–septate, less than 1 per cent, 18 x 3.5μ
2–septate, 2 per cent, 24 x 4.0μ
3–septate, 20 per cent, 36 x 4.0μ
4–septate, 12 per cent
5–septate, 63 per cent, 50 x 4.3μ
6– and 7–septate, 3 per cent, 68 x 4.8μ

F. effusum, especially in its sporodochial stage, much resembles the following other species: *F. subulatum*, *F. lucidum*, *F. biforme*, *F. diversisporum*. From *F. subulatum* it can be at once distinguished by the diameter of the conidia and by the larger size of sporodochia.[40] From *F. lucidum* it differs primarily by the common presence of 6– and 7–septate conidia, which are absent in *F. lucidum*, and by denser red substratum than that of the latter species. From *F. biforme* it differs mainly by absence of the long, 9– or more septate, conidia in pseudopionnotes, and also by absence of arthrosporial conidial form, the pluriseptate conidia and arthrosporial conidia on aërial mycelium being more or less common in *F. biforme*. From *F. diversisporum* it differs by absence of arthrosporial conidia, which are typically produced on aërial mycelium of *F. diversisporum*.

[40] Sporodochia of *F. subulatum* as a rule are small, but on whole steamed potato tubers they may be as large as those of *F. effusum*.

17. Fusarium truncatum n. sp. (Figs. 1, C_1 to E_1, and 14; Pl. VII, fig. 1)

Conidia typically sickle-shaped, gradually pointed toward the apex, slightly broader at or just above the middle, distinctly pedicellate, 3- to 5-septate; 3-septate averaging 35 x 3,7 (31.5–42 x 3.4–3.9)μ, 5-septate averaging 45 x 3.9 (43–48 x 3.4–4.2)μ; from cinnamon and terra cotta to carmine-pomegranate purple in color; conidiophores from loose to dense, bushlike, single or in from small to large (up to ½ centimeter in diameter) sporodochia; aërial mycelium always well developed, mostly composed of fine but macroscopically distinct threads, from white to slightly carmine near substratum; color of substratum, on hard potato agar rich in glucose,

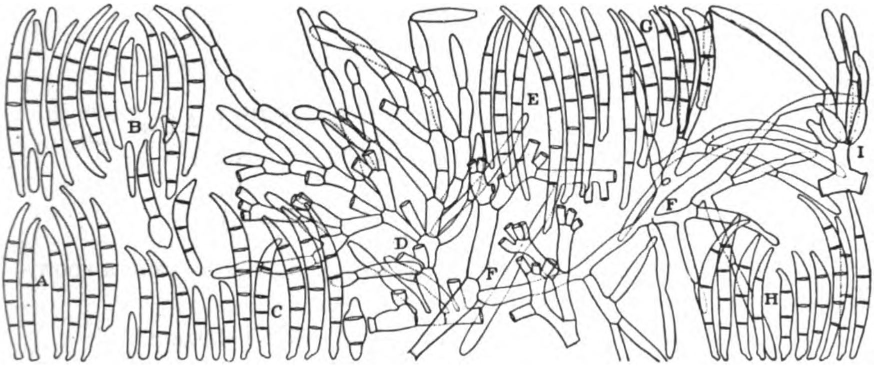

FIG. 14.—*Fusarium truncatum.* A, *Sporodochial conidia from 60-days-old culture on red raspberry cane plug;* B, *aërial conidia from 13-days-old culture on hard potato agar;* C, *aërial conidia (some with distinctly truncate basal cell) from 14-days-old culture on medium potato agar;* D, *conidiophore from 13-days-old culture on hard potato agar;* E, *sporodochial conidia from 14-days-old culture on medium potato agar;* F, *conidiophores from 47-days-old culture on potato tuber plug;* G, *sporodochial conidia from 37-days-old culture on hard oat agar;* H, *conidia from aërial mycelium from 47-days-old culture on potato tuber plug;* I, *conidiophore from 4-days-old colony in petri dish on hard potato agar with 10 per cent glucose*

varies from pale cinnamon and diffuse salmon hues to corinthian and brick red, more or less distinctly zonate.

Hab. On rotted tubers of *Solanum tuberosum*, New York State.

Latin description.—Conidiis typice falciformibus, gradatim in apicem acutis, paulo latioribus medio vel subinde supra medium, distincte pedicellatis 3–5–septatis; 3–septatis plerumque 35 x 3.7 (31.5–42 x 3.4–3.9)μ, 5–septatis plerumque 45 x 3.9 (43–48 x 3.4–4.2)μ; e "cinnamon" (R) et "terra cotta" (R) "carmine" (R) et "pomegranate purple" (R); co-

nidiophoris laxis demum dense, fruticosis, continuis vel in parvis magnisve (usque ad ½ cm. diam.) sporodochiis; aerio mycelio semper plene maturo, ex hyphis subtilibus sed macroscopice distinctis composito, ex albo paulum "carmine" (R) prope substratum; substrato in duro agare glucoso Solani tuberosi e pallide "cinnamon" (R) et "salmon color" (R) diffuse "corinthian" et "brick red" (R), plus minusve distincte zonato.

Hab. In tuberibus putridis Solani tuberosi, New York, Amer. bor.

Measurements of conidia from cultures on different media are as follows:

On slightly acidified hard potato agar, culture thirteen days old; conidia from aërial mycelium:

Conidia: 0–septate, 7 per cent
1–septate, 54 per cent
2–septate, 6 per cent
3–septate, 22 per cent, 31.5 x 3.75 (21–45 x 3.1–4.1)μ
4–septate, 4 per cent, 40 x 4.1 (32–49 x 3.5–4.7)μ
5–septate, 7 per cent, 43 x 4.1 (33–53 x 3.9–4.7)μ
6–septate, rare, 45 x 4.5μ (only two measured)

On potato tuber plugs, culture forty-six days old; conidia from a sporodochium 2 millimeters in diameter:

Conidia: 3–septate, 63 per cent, 37 x 3.4 (27–49 x 3–3.6)μ
4–septate, 22 per cent, 41 x 3.7 (40–45 x 3.5–4)μ
5–septate, 15 per cent, 43 x 3.7 (40–45 x 3.5–4.1)μ

On red raspberry cane plug, culture sixty days old; conidia from a sporodochium about 2 millimeters in diameter:

Conidia: 3–septate, 29 per cent, 37 x 3.9 (28–41 x 3.5–4.2)μ
4–septate, 31 per cent, 40 x 3.9 (35–43 x 3.5–4.2)μ
5–septate, 40 per cent, 44 x 4 (36–46 x 3.5–4.5)μ

On potato stem plug, culture eighty-three days old; conidia from a sporodochium about 1½ millimeters in diameter (many of the conidia much deteriorated):

Conidia: 3–septate, 20 per cent
4–septate, 16 per cent
5–septate, 64 per cent, 48 x 3.4 (44–51 x 3.1–3.7)μ

On soft potato agar, plate culture fourteen days old; conidia from thick pseudopionnotal mass near the inoculation point:

Conidia: 3–septate, 20 per cent, 42 x 3.4 (35–51 x 3–3.9)μ
4–septate, 13 per cent
5–septate, 67 per cent, 50 x 3.6 (43–65 x 3.1–3.9)μ

On same medium as above, plate culture also; conidia from a small sporodochium on aërial mycelium:

Conidia: 0–septate, rare
1–septate, 3 per cent, 16 x 3.1μ (only one measured)
2–septate, 2 per cent, 21 x 3.5μ (only one measured)
3–septate, 29 per cent, 33 x 3.8 (22–41 x 3.3–4.2)μ
4–septate, 19 per cent
5–septate, 47 per cent, 45 x 4.2 (36–64 x 4–4.4)μ

Average of the above measurements:

Conidia: 0–septate, about 1 per cent
1–septate, about 9 per cent
2–septate, about 1 per cent
3–septate, about 31 per cent, 34.8 x 3.7μ
4–septate, about 18 per cent
5–septate, about 40 per cent, 45 x 3.9μ
6–septate, very exceptional, 45 x 4.5μ (only two measured)

Conidia of *F. truncatum* often have a peculiar flat base, and this species can be separated from all the other Fusaria of potatoes by its typically (though not always) pomegranate purple to carmine conidial masses.

18. **Fusarium lucidum** n. sp. (Figs. 1v and 15; Pl. II, figs. 9 and 10; Pl. IV, fig. 12; Pl. VI, fig. 12)

Conidia typically ellipsoid, very gradually attenuate toward both ends, distinctly but not prominently pedicellate, 5–septate, 54 x 4.05 (43–63 x 3.7–4.7)μ, salmon, often of very bright hues, but paler or denser in from small to large (up to ½ centimeter in diameter) sporodochia; no chlamydospores; conidiophores typically more or less compound, bushlike; mycelium from white to pale cinnamon and pomegranate near substratum; when first isolated the fungus has a substratum, on potato agar without glucose from pale pink to tints of pomegranate, and on the same medium with glucose from clay to buckthorn brown.

Hab. On rotted tubers of *Solanum tuberosum*, New York State.

Differs from *F. effusum* mainly by absence or very rare occurrence of 6– and 7–septate conidia.

Latin description.—Conidiis typice ellipsoidalibus, maxime in utrosque terminos gradatim attenuatis, distincte sed non insignite pedicellatis, 5–septatis, 54 x 4.05 (43–63 x 3.7–4.7)μ, "salmon-color" (R) magnis, in parvis (usque ad ½ cm. diam.) sporodochiis; nullis chlamydosporis; conidiophoris typice plus minusve compositis, fruticosis; mycelio ex albo "pale cinnamon" (R) vel "pomegranate" (R) prope substratum; primum

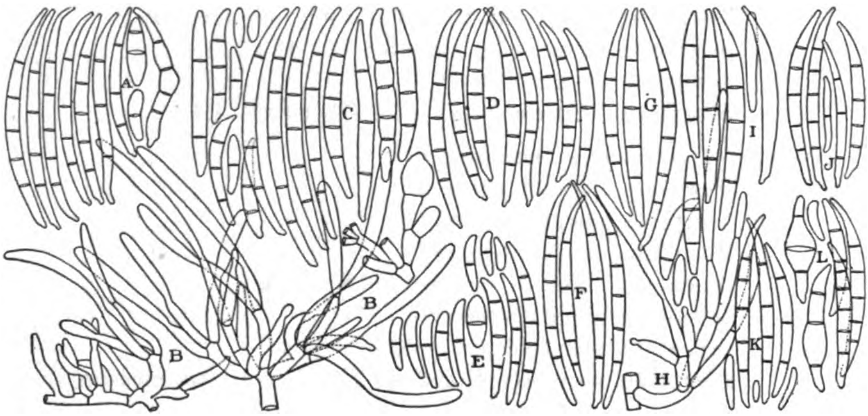

FIG. 15.—*Fusarium lucidum.* A, *Sporodochial conidia,* B, *conidiophores, from 47-days-old culture on wheat kernels;* C, *pseudopionnotal conidia from 11-days-old culture on slightly acidified hard potato agar;* D, *sporodochial,* E, *aërial, conidia from 75-days-old red raspberry cane plug;* F, *pseudopionnotal conidia from 36-days-old culture on hard oat agar;* G, *sporodochial conidia,* H, *conidiophore, from 20-days-old culture on hard lima-bean agar with 2 per cent glucose;* I, *pseudopionnotal conidia from 7-days-old culture on hard lima-bean agar with 2 per cent glucose;* J, *sporodochial conidia from 65-days-old culture on potato stem plug;* K, *sporodochial conidia from 24-days-old culture on potato tuber plug;* L, *sporodochial conidia from 82-days-old culture on potato tuber plug (the two at the left abnormal)*

substrato, in agare Solani tuberosi non glucoso, e pallide rubello "pomegranate" (R) vel simili colore, in eodem agare glucoso, ex argillaceo "buckthorn-brown" (R).

Hab. In tuberibus putridis Solani tuberosi, New York, Amer. bor.

Measurements of conidia from cultures on different media are as follows:

On hard potato agar, slightly acidified, culture eleven days old; conidia from pseudopionnotes:

Conidia: 0–septate, rare
1–septate, 11 per cent, 17 x 3.1 (12–22 x 2.9–3.5)μ
2–septate, 7 per cent, 28 x 3.8 (20–32 x 2.9–4.3)μ
3–septate, 68 per cent, 43.7 x 3.8 (33–67 x 3–4.4)μ
4–septate, 4 per cent, 55 x 4.2 (47–65 x 4–4.4)μ
5–septate, 10 per cent, 63 x 4.4 (57–72 x 4–4.8)μ

On red raspberry cane plug, culture seventy-five days old; conidia from aërial mycelium:

Conidia: 0–septate, rare
1–septate, 1 per cent
3–septate, 5 per cent, 43 x 3.8 (25–48 x 3.5–4.4)μ
4–septate, 14 per cent, 45 x 3.8 (38–54 x 3–4.6)μ
5–septate, 80 per cent, 51 x 4.2 (42–60 x 3.5–4.7)μ
6–septate, rare

On potato tuber plugs, culture ninety-two days old; conidia from a mass of minute sporodochia:

Conidia: 0–septate, rare
1–septate, 3 per cent
2–septate, 2 per cent
3–septate, 25 per cent, 31 x 3.8 (24–36 x 3–4.1)μ
4–septate, 17 per cent
5–septate, 53 per cent, 46 x 3.9 (36–58 x 3.5–4.7)μ
6–septate, rare, 55–60 x 3.8–4.7μ (only a few measured)

On hard lima-bean agar with 2 per cent glucose, culture seven days old; conidia from aërial mycelium:

Conidia: 0–septate, 40 per cent
1–septate, 35 per cent
2–septate, 5 per cent
3–septate, 14 per cent, 41 x 4.2 (33–44 x 3.5–4.8)μ
4–septate, 5 per cent, 48 x 4.6 (42–53 x 4–5.3)μ
5–septate, 1 per cent, 56 x 4.7 (53–58 x 4.3–4.9)μ (only five spores measured, the largest 60 x 5.7μ)

On the same medium as above, culture twenty days old; conidia from a small sporodochium:

Conidia: 3–septate, 1 per cent
4–septate, 12 per cent, 44 x 4 (40–57 x 3.5–4.4)μ
5–septate, 87 per cent, 54 x 3.9 (40–68 x 3.5–4.2)μ

On potato tuber plug, culture twenty-four days old; conidia from aërial mycelium:

Conidia: 3–septate, 10 per cent, 46 x 3.4μ (only a few measured)
4–septate, 30 per cent, 47 x 3.5 (44–50 x 3–3.8)μ
5–septate, 60 per cent, 51 x 3.7 (48–57 x 3.4–4.2)μ
6–septate, rare, 60 x 4.2μ (only one measured)

On potato stem plug, culture one hundred and seven days old; conidia from a sporodochial mass (much deterioated):

Conidia: 3–septate, 15 per cent
4–septate, 5 per cent
5–septate, 80 per cent, 56 x 3.8 (50–63 x 3.5–4.2)μ

On steamed whole potato tuber, culture forty-nine days old; conidia from a white, semi-dry, sporodochial mass:

Conidia: 3–septate, 50 per cent, 36 x 3.9 (24–43 x 3.5–4.1)μ
4–septate, 35 per cent
5–septate, 15 per cent, 43 x 4.1 (39–46 x 3.9–4.4)μ

On same medium as above; conidia from a red (old?) sporodochial mass, nearly converging into semi-pionnotal layer:

Conidia: 0–septate, very rare
3–septate, 8 per cent, 46 x 3.7 (24–50 x 3–4)μ
4–septate, 12 per cent, 48 x 3.8 (41–52 x 3.5–4.1)μ
5–septate, 80 per cent, 54 x 4 (43–62 x 3.5–4.3)μ
6–septate, very rare, about 57 x 4.2μ (only a few measured)

On medium soft potato agar, culture fourteen days old; conidia from pseudopionnotes:

Conidia: 3–septate, 28 per cent, 42 x 3.6μ (only four measured)
4–septate, 10 per cent
5–septate, 62 per cent, 58 x 4 (43–65 x 3.5–4.7)μ

On hard lima-bean agar, culture fourteen days old; conidia from a sheet of small sporodochial masses spread over the substratum:

Conidia: 3–septate, 3 per cent, 41 x 3.2μ (only three measured)
4–septate, 1 per cent
5–septate, 96 per cent, 60 x 3.8 (52–70 x 3.5–5)μ

On wheat grain culture fourteen days old; conidia from small, semi-dry sporodochia:

Conidia: 1–septate, rare
3–septate, 14 per cent
4–septate, 26 per cent
5–septate, 60 per cent, 56 x 3.7 (49–64 x 3.3–4.1)μ

Average of the above measurements:

Conidia: 0–septate, about 3 per cent
1–septate, about 4 per cent, 17 x 3.1μ
2–septate, about 1 per cent
3–septate, about 20 per cent, 41 x 3.7μ
4–septate, about 14 per cent
5–septate, about 58 per cent, 54 x 4.05μ
6–septate, very rare, 58 x 4.2μ

VI. SECTION **ARTHROSPORIELLA** n. sec.

Microconidia short and broad, spindle-shaped, 0– to 3–septate[41]; sporodochial macroconidia when present sickle-shaped, mostly 5–septate, of Roseum type; pseudopionnotal microconidia mostly 5– and 5– to 7–, often to 9– and more, septate, from slightly curved to straight and anguiform; true chlamydospores absent; aërial mycelium from white to pale buff and different hues of red and pink; color of substratum from clay to different hues of red.

The section is a connecting link between sections Roseum and Sporotrichiella (through *F. arthrosporioides*).

19. **Fusarium diversisporum** n. sp. (Fig. 16; Pl. VII, fig. 12)

Conidia varying from arthrosporial (short, spindle-shaped, and having an average measurement when 3–septate and on aërial mycelium of 28 x

[41] These conidia, though often septate, represent an abbreviated type and thus can be termed microconidia. These microconidia are often referred to as arthrosporial because of their resemblance to the conidia of the genus Arthrosporium.

4.3μ) to sickle-shaped, 5-septate type dominant, in sporodochia and pseudopionnotes, measuring 48.5 x 3.63 (41–61 x 2.9–4.4)μ; in pseudopionnotes, 6- to 9-septate conidia are common, 60–100 x 4.7–5.2μ, from slightly curved to straight and anguiform, apically pointed, distinctly but not prominently pedicellate, in mass typically of light pink-cinnamon color; chlamydospores absent; sporodochia when present often of a large size (up to 1.7 centimeters in diameter); aërial mycelium typically well developed, of uniformly medium fineness, white; substratum, on potato

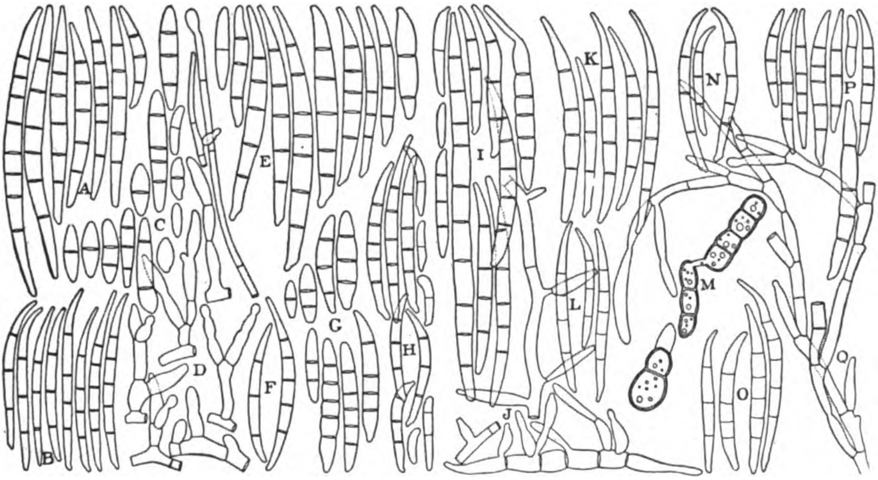

FIG. 16.—*Fusarium diversisporum.* A, *Pseudopionnotal conidia from 26-days-old culture on hard oat agar;* B, *sporodochial conidia,* C, *arthrosporial conidia,* D, *aërial conidiophores producing arthrosporial conidia, from 76-days-old culture on red raspberry cane plug;* E, *pseudopionnotal conidia from 8-days-old culture on hard lima-bean agar with 2 per cent glucose;* F, *typical sporodochial conidia from 113-days-old culture on potato stem plug;* G, *sickle-shaped, normal conidia,* H, *arthrosporial, more or less abnormal, conidia, from aërial mycelium of 45-days-old culture on whole steamed potato tuber;* I, *pseudopionnotal conidia,* J, *mycelial conidiophores and conidiophores produced directly on spores,* K, *conidia, from 10-days-old culture on medium potato agar;* L, *typical sporodochial conidia from 46-days-old culture on whole steamed potato tuber;* M, *chlamydospore-like structures in old conidia from 173-days-old culture on corn agar;* N, *sporodochial conidia from 42-days-old culture on rye straw;* O, *sporodochial conidia from 116-days-old culture on rye straw;* P, *sporodochial conidia from 24-days-old culture on potato tuber plug;* Q, *conidiophore from 24-days-old culture on potato tuber plug*

agar rich in glucose, ranging from onion-skin pink and clay color when young to Saccardo's amber in old cultures.

Hab. On rotted tubers of *Solanum tuberosum*, New York State, in close association with *F. metacroum.*

Latin description.—Conidiis ex arthrosporialibus (brevibus, falciformibus, atque, si 3–septata et in aerio mycelio, plerumque 28 x 4.3μ), falciformibus plerumque 5–septatis, 48.5 x 3.63 (41–61 x 2.9–4.4)μ in sporodochiis pseudopionnotibusque; in pseudopionnotibus, conidiis 6–9–septatis frequentibus, 60–100 x 4.7–5.2μ, parum curvatis rectis, demum anguiformibus, apice acutis, distincte sed non insignite pedicellatis, in totum typice pallide "pinkish cinnamon" (R); nullis chlamydosporis; sporodochiis, si exstant, saepe magnis (usque ad 1.7 cm. diam.); aerio mycelio typice plene maturo, uniformi mediocri subtilitate, albo; substrato—in Solani tuberosi agare perglucoso—in culturis juvenibus, "onion-skin pink" (R) vel "clay-color" (R), in culturis maturis "Saccardo's amber" (R).

Hab. In tuberibus putridis Solani tuberosi una cum F. metacroo, New York, Amer. bor.

Measurements of conidia from cultures on different media are as follows:

On slightly acidified hard potato agar, culture ten days old; conidia from thin pseudopionnotes:

Conidia: 0–septate, rare
1–septate, 7 per cent, 10 x 2.4μ
2–septate, 1 per cent, 20 x 2.9μ
3–septate, 36 per cent, 36 x 3.1 (29–46 x 2.9–3.5)μ
4–septate, 20 per cent, 49 x 3.15 (40–53 x 3–4)μ
5–septate, 35 per cent, 60 x 3.8 (50–70 x 3.5–4.2)μ
6– to 9–septate, 1 per cent (60–100 x 4–5μ)

On red raspberry cane plug, culture seventy-six days old; conidia from a small sporodochium:

Conidia: 3–septate, 57 per cent, 40 x 2.7(32–45 x 2.4–3)μ
4–septate, 28 per cent, 45 x 2.9(42–52 x 2.6–3.2)μ
5–septate, 15 per cent, 50 x 2.9(43–54 x 2.7–3.2)μ

On hard lima-bean agar, culture eight days old; conidia from a thin layer near substratum:

Conidia: 1–septate, 2 per cent
2–septate, 1 per cent
3–septate, 32 per cent, 37 x 3.9 (28–43 x 3.5–5.3)μ
4–septate, 9 per cent

5–septate, 55 per cent, 54 x 4.4 (40–61 x 3.5–5.5)μ

6–septate	1 per cent	61 x 4.9 (60–70 x 4.7–5.2)μ (only four measured)
7–septate		67 x 5 (60–79 x 4.7–5.2)μ (only four measured)
8–septate		76 x 4.8 (70–79 x 4.7–4.8)μ (only three measured)

On potato tuber plug, culture twenty-four days old; conidia from a sporodochium, many spores degenerated, only normal ones measured:

Conidia: 0–septate, none
1–septate, 4 per cent
2–septate, none
3–septate, 50 per cent, 32 x 3.1 (20–40 x 2.7–3.5)μ
4–septate, 22 per cent
5–septate, 24 per cent, 42 x 3.5 (35–51 x 3–3.6)μ

On potato stem plug, culture one hundred and thirteen days old; conidia from a sporodochium:

Conidia: 3–septate, 25 per cent, about 38 x 3.3μ
4–septate, 25 per cent, about 40 x 3.4μ
5–septate, 50 per cent, 42 x 3.5 (36–46 x 3–4.1)μ

On whole steamed potato tuber, culture forty-five days old:

(1) Conidia from aërial mycelium

Conidia: A — Arthrosporial type
1–septate, 10 per cent, about 10 x 3.9μ
2–septate, 3 per cent, 16 x 4μ
3–septate, 71 per cent, 28 x 4.3 (19–37 x 4–5)μ
4–septate, 6 per cent
5–septate, 10 per cent, 41 x 4.2 (37–46 x 4.1–4.5)μ

B — Sickle-shaped type
0–septate, 6 per cent, about 10 x 2.6μ
1–septate, 22 per cent, 16 x 2.8 (13–19 x 2.4–3)μ
2–septate, 4 per cent, about 21 x 2.9μ
3–septate, 40 per cent, 30 x 3.1 (20–34 x 2.9–3.5)μ
4–septate, 12 per cent, about 39 x 3.2μ
5–septate, 16 per cent, 45 x 3.3 (38–53 x 3–3.6)μ

(2) Conidia from small sporodochia converging into a nearly continuous layer

Conidia: 3–septate, 45 per cent, 33 x 3.1 (20–41 x 2.5–3.5)μ
4–septate, 28 per cent, 40 x 3.2μ (only a few measured)
5–septate, 27 per cent, 43 x 3.3 (36–50 x 2.9–4.1)μ

On hard lima-bean agar, culture thirteen days old; conidia from pseudopionnotal stage:

Conidia: 3–septate, about 12 per cent, 48 x 3μ (only three measured)
4–septate, about 8 per cent
5–septate, 80 per cent, 61 x 3.3 (50–70 x 3.1–3.5)μ

On hard oat agar, culture thirty-seven days old; conidia from aërial mycelium close to substratum:

Conidia: 1–septate, 1 per cent
3–septate, 20 per cent, 31 x 3.3μ
4–septate, 15 per cent
5–septate, 60 per cent, 45 x 3.7 (43–49 x 3.3–4)μ
6–septate, 4 per cent, 61 x 4.2μ (only one measured)

On same medium as above, culture twenty-four days old; conidia from pseudopionnotes:

Conidia: 3–septate, 10 per cent, 28 x 3.3μ
4–septate, 4 per cent
5–septate, 50 per cent, 51 x 4μ
6–septate, 30 per cent, 60.6 x 4.2μ
7– and 8–septate, 6 per cent, 75 x 43μ

Average of the above measurements:

Conidia: 0–septate, about 0.5 per cent, 10 x 3.25μ
1–septate, about 4 per cent, 12 x 3.0μ
2–septate, about 0.5 per cent
3–septate, about 35.5 per cent, 36 x 3.2μ
4–septate, about 15 per cent
5–septate, about 44 per cent, 48.5 x 3.63μ
6– to 9–septate, about 0.5 per cent, 60–100 x 4.7–5.2μ

The most characteristic features of the fungus are as follows: 0– to 3–septate, spindle-shaped conidia of aërial mycelium; 3– to 5–septate,

very narrow sickle-shaped conidia of sporodochia, and comparatively broad and longer anguiform; 6- to 9-septate conidia of pseudopionnotal stage often occurring on various agars.

20. **Fusarium biforme** n. sp. (Figs. 1U and 17; Pl. VII, fig. 10)

Conidia of two forms: sporodochial conidia more or less uniformly ellipsoid, 3- to 5-septate, 3-septate measuring 39 x 3.3 (36–46 x 2.9–3.6)μ, 5-septate measuring 51 x 3.5 (43–60 x 3–4)μ; pseudopionnotal conidia 0- to 9- and even up to 12-septate, sometimes nearly straight or anguiform, 5-septate measuring 52 x 4.2μ, 6- to 9-septate measuring 45–84 x 4–5.8μ; conidia in mass typically salmon-colored; no chlamydospores; mycelium

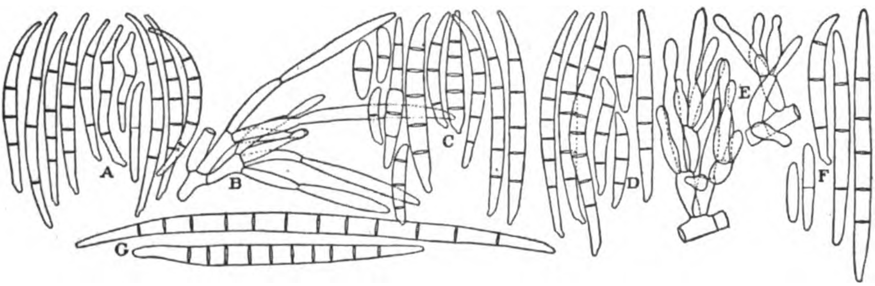

FIG. 17.—*Fusarium biforme.* A, *Conidia (sporodochium 3 millimeters in diameter),* B, *conidiophore, from 29-days-old culture on hard oat agar;* C, *conidia from aërial mycelium from 71-days-old culture on potato tuber plug;* D, *semi-pseudopionnotal conidia from 14-days-old culture on slightly acidified hard potato agar;* E, *conidiophores,* F, *typical conidia,* G, *largest and most highly septate conidia, from 10-days-old culture on rice*

well developed, uniform, white in pseudopionnotal stage and from pink to pomegranate near substratum in sporodochial stage (on hard oat agar);[42] substratum from brick red to pomegranate (on oat and other agars).

Hab. On rotted tuber of *Solanum tuberosum*, together with *F. coeruleum*, Wisconsin.

Differs from *F. diversisporum* chiefly in color of mycelium and of substratum on hard oat agar and other agars, and in absence of a uniform and typical arthrosporial stage of aërial conidia, although single conidia of that type occur here also. Differs from *F. effusum* by the presence of 8- to 12-septate conidia.

[42] On the same medium *F. diversisporum* remains from white to clay in color.

Latin description.—Conidiis biformibus: conidiis sporodochialibus, plus minusve aequabiliter ellipsoidalibus, 3–5–septatis: 3–septatis, 39 x 3.3 (36–46 x 2.9–3.6)μ; 5–septatis 51 x 3.5 (43–60 x 3–4)μ; conidiis pseudo-pionnotalibus 0–9–septatis vel etiam 12–septatis, interdum prope rectis vel anguiformibus; 5–septatis, 52 x 4.2μ; 6–9–septatis, 45–84 x 4–5.8μ; conidiis in totum typice "salmon-color" (R); nullis chlamydosporis; mycelio plene maturo, uniformi, albo in pseudopionnotum gradu, ex rubello "pomegranate" (R) in gradu sporodochiali (in durae avenae agare); substrato e "brick red" (R) "pomegranate" (R) (in avenae agaribus et aliis agaribus).

Hab. In tuberibus putridis Solani tuberosi una cum F. coeruleo, Wisconsin, Amer. bor.

Measurements of the conidia on different media are as follows:

On corn agar, culture twenty-six days old; conidia from a thin layer directly on substratum;

Conidia: 1– to 4–septate, 20 per cent (about an equal number of each)
5–septate, 45 per cent, 60 x 3.6 (50–70 x 3.4–3.8)μ
6– to 9–septate, 35 per cent, 80 x 4.4 (77–88 x 4.1–4.7)μ

On hard potato agar, slightly acidified, culture fourteen days old; conidia from aërial mycelium close to substratum:

Conidia: 0–septate, 0.5 per cent, 12 x 3μ
1–septate, 3 per cent, 19 x 3μ
2–septate, rare, 25 x 3.2μ
3–septate, 5 per cent, 32 x 3.7 (24–51 x 3.5–4.2)μ
4–septate, 2.5 per cent
5–septate, 80 per cent, 51.5 x 4.3 (40–74 x 4–5.2)μ
6–septate, 6 per cent, 58 x 4.7 (50–75 x 4.3–5.3)μ
7– and 8–septate, 3 per cent, 68 x 4.7 (55–80 x 4.3–5.3)μ
9– to 11–septate, rare, 84 x 5.9μ (only a few measured)

On potato tuber plug, culture seventy-one days old; conidia from aërial mycelium close to substratum:

Conidia: 0–septate, 2 per cent, 9 x 3μ
1–septate, 6 per cent, 14 x 3.3μ, a few 15 x 5.7μ
2–septate, 3 per cent, 20 x 3.4μ
3–septate, 30 per cent, 27.5 x 3.9 (19–39 x 3.5–4.1)μ
4–septate, 12 per cent

5–septate, 44 per cent, 43 x 4.1 (31-54 x 3.9–5.2)μ
6–septate, 2 per cent, 49 x 4.3 (45–72 x 4–4.9)μ
7–septate, 1 per cent, 60 x 4.8 (59–73 x 4.1–5.3)μ
8– and 9–septate, rare, 60–78 x 4.5–5.8μ (only a few measured)

On hard lima-bean agar with 2 per cent glucose, culture seven days old; conidia from aërial mycelium:

Conidia: 0– and 1–septate, 79 per cent
3–septate, 15 per cent, 36 x 4.6 (33–41 x 4.3–4.7)μ
4–septate, 5 per cent
5–septate, 1 per cent, 54 x 4.7 (53–66 x 4.3–5.3)μ

On hard oat agar, culture twenty-eight days old; conidia from a large (3 millimeters in diameter) sporodochium:

Conidia: 1–septate, 3 per cent, about 28 x 3 (28–37 x 2.3–3)μ
2–septate, 1 per cent
3–septate, 45 per cent, 39 x 3.3 (36–46 x 2.9–3.6)μ
4–septate, 16 per cent
5–septate, 35 per cent, 51 x 3.5 (43–60 x 3–4)μ

Average of the above measurements for all non-sporodochial conidia:

Conidia: 0–septate, about 9 per cent, 11 x 3μ
1–septate, about 11 per cent, 16.5 x 3.15μ
2–septate, about 2 per cent
3–septate, about 20 per cent, 32 x 4.1μ
4–septate, about 8 per cent
5–septate, about 41 per cent, 52 x 4.2μ
6– to 9–septate, about 9 per cent, 45–84 x 4–5.8μ

The organism when first isolated had large sporodochia (from 2 to 5 millimeters in diameter), and the substratum and mycelium near it were from rose to pomegranate in color; later the color of mycelium and substratum faded and no sporodochia were produced at all; during the last year its original characters — both color and sporodochia — reappeared. Under just what influence loss of characters and their reappearance took place the writer is unable to say, although it seems that a slightly acidified and relatively dry medium actually helped to bring the fungus to the original conditions.

21. Fusarium anguioides n. sp. (Figs. 1T and 18; Pl. VI, fig. 11)

Conidia of diverse type, ranging from arthrosporial (short spindle-shaped, with more or less rounded ends, 0– to 3–septate) to typically slightly curved or nearly straight and anguiform, 1– to 15–septate; 1– and 3–septate conidia typical for the first form and measuring 27 x 4.4 (20–38 x 3.9–5.3)μ; for the other form the conidia commonly measuring as follows:

5–septate, 51 x 4.2 (47–68 x 3.9–4.6)μ
6– and 7–septate, 76 x 4.6 (65–86 x 4.2–5.2)μ
8– and 9–septate, 89 x 4.86 (80–102 x 4.3–5.8)μ

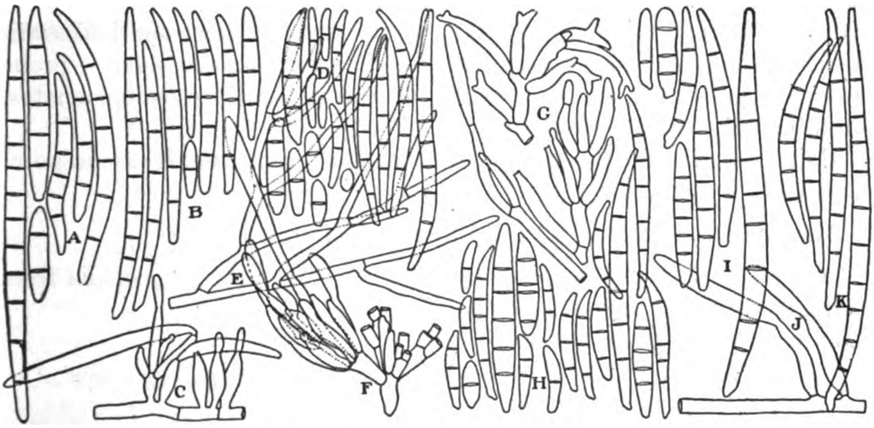

FIG. 18.—*Fusarium anguioides.* A, *Pseudopionnotal conidia from 6-days-old culture on slightly acidified hard potato agar;* B, *conidia from 15-days-old culture on wheat grain;* C, *conidiophores from 6-days-old culture on slightly acidified hard potato agar;* D, *conidia from 46-days-old culture on wheat grain;* E, *conidiophore from 15-days-old culture on wheat grain;* F *and* G, *conidiophores,* H, *conidia, from 62-days-old culture on red raspberry cane plug;* I, *pseudopionnotal conidia from 11-days-old culture on medium potato agar;* J, *conidiophores from 62-days-old culture on red raspberry cane plug;* K, *pseudopionnotal conidia from 13-days-old hard lima-bean agar*

Color of conidia in pseudopionnotal layer, on glucose potato agar, ranging from light pinkish cinnamon to cinnamon; arthrosporial conidia of common occurrence on aërial mycelium, but often the latter, especially on different agar, nearly absent, when a thin spore layer, pseudopionnotes, is produced for which anguiform conidia are typical.

Hab. On rotted tuber of *Solanum tuberosum* from Castile, New York, in association with *F. arcuosporum.*

In pseudopionnotal stage *F. anguioides* is much like *F. biforme*, but has no sporodochial stage, or rather no macroscopically observable sporodochia.

Latin description.—Conidiis variis typis, interdum arthrosporialibus (brevibus, fusiformibus, terminis plus minusve rotundatis, 0–3–septatis), interdum typice paulum curvatis vel prope rectis anguiformibusque, 1–15–septatis; conidiis primo typo typice 1–vel 3–septatis, 27 x 4.4 (20–38 x 3.9–5.3)μ; conidiis altero typo: 5–septatis plerumque 51 x 4.2 (47–68 x 3.9–4.6)μ; 6–7–septatis plerumque 76 x 4.6 (65–86 x 4.2–5.2)μ; 8–9–septatis plerumque 89 x 4.86 (80–102 x 4.3–5.8)μ. Conidiis in strato pseudopionnotali, in agari glucoso Solani tuberosi e pallide "pinkish-cinnamon" (R) "cinnamon" (R); saepe conidiis arthrosporialibus in aerio mycelio, sed hoc mycelio saepe—imprimis in alio agari—prope absente, quae cum ita sint tenues sporarum strati, pseudopionnotes, oriuntur cum conidiis typice anguiformibus.

Hab. In tuberibus putridis Solani tuberosi, una cum F. arcuosporo, Castile, New York, Amer. bor.

Measurements of conidia on different media are as follows:

On red raspberry cane plug, culture sixty-two days old; conidia from aërial mycelium close to substratum:

Conidia: 0–septate, 3 per cent
1–septate, 19 per cent, 17 x 3 (12–22 x 2.5–4)μ
2–septate, 9 per cent
3–septate, 43 per cent, 30 x 3.5 (17–42 x 3–4.8)μ
4–septate, 7 per cent
5–septate, 18 per cent, 47 x 4.2 (35–55 x 3–5.2)μ, the thickest 50 x 5.9μ
6–septate, 1 per cent
7–septate, rare, the longest 75 x 4.8μ

On hard potato agar, culture eleven days old; conidia from thin pseudopionnotes:

Conidia: 1–septate, 3 per cent, 18 x 4.3μ (only a few measured)
2–septate, 2 per cent
3–septate, 20 per cent, 29 x 4.5 (20–35 x 4–6.5)μ, the broadest 34 x 6.5μ
4–septate, 10 per cent

5–septate, 44 per cent, 52 x 4.6 (33–75 x 4.1–6.2)μ

6–septate 7–septate	9 per cent	72 x 5.2μ (only a few measured)
8–septate 9–septate	8 per cent	80 x 5.3μ (only a few measured) 102 x 5.8μ (only a few measured, the largest 105 x 6.5μ)
11–septate 12–septate	4 per cent	91 x 5.8μ (only one measured) 101 x 5.7μ (only one measured)

On hard lima-bean agar, culture thirteen days old; conidia from thin pseudopionnotes:

Conidia: 5–septate, 9 per cent, 58 x 4.1 (53–62 x 3.9–4.4)μ
6–septate, 12 per cent, 78 x 4.3 (70–87 x 4.1–4.5)μ
7–septate, 19 per cent, 86 x 4.3 (78–96 x 4.1–4.5)μ
8–septate, 32 per cent, 93 x 4.4 (86–100 x 4.2–4.8)μ
9–septate, 17 per cent, 94 x 4.4 (90–100 x 4.2–4.7)μ
10–septate, 7 per cent, 94 x 4.4 (97–103 x 4.3–4.5)μ (only four measured)
11–septate, 2 per cent, 108 x 4.4μ (only one measured)
12–septate, 1 per cent, 110 x 4.4μ (only one measured)
13–septate, 1 per cent, 126 x 4.8μ (only one measured)

On wheat grain, culture fifteen days old; conidia from aërial mycelium:

Conidia: 0–septate, very rare
1–septate, very rare
2–septate, very rare, 26 x 3.1μ (only a few measured)
3–septate, 5 per cent
4–septate, 2.5 per cent
5–septate, 89 per cent, 60 x 4.2 (45–70 x 3.9–4.7)μ

6–septate 7–septate	3 per cent	75 x 4.2 (67–80 x 4.1–4.4)μ (only a few measured) 85 x 4.3μ (only a few measured)
8–septate 9–septate	0.5 per cent	81 x 4.6μ (only a few measured) 86 x 4.5μ (only a few measured, the longest 92 x 4.5μ)

On hard lima-bean agar, culture nine days old; conidia from pseudo pionnotes:

Conidia: 0–septate
1–septate } 1 per cent
2–septate
3–septate, 2 per cent, 45 x 4 (only a few measured)
5–septate, 40 per cent, 63 x 4.3 (43–76 x 3.5–4.7)μ
6–septate, 22 per cent, 72 x 4.4 (62–79 x 4–4.7)μ
7–septate, 18 per cent, 80 x 4.5 (63–88 x 4.3–4.8)μ
8–septate, 10 per cent, 87 x 4.7 (75–93 x 4.3–4.8)μ
9–septate, 5 per cent, 88 x 4.7μ (only two measured)
10–septate, 2 per cent, 90 x 4.8μ (only one measured)

On wheat grain, culture forty-six days old; conidia from aërial mycelium close to substratum:

Conidia: 0–septate, 3 per cent: arthrosporial, 15 x 4.1 (10–22 x 3.9–4.4)μ; sickle-shaped, 20 x 2.8 (16–22 x 2.6–3.5)μ
1–septate, 27 per cent
2–septate, 4 per cent } arthrosporial, 27 x 4.4 (20–38 x 3.9–5.3)μ
3–septate, 38 per cent
4–septate, 11 per cent
5–septate, 15 per cent, 53 x 3.9 (42–62 x 3.5–4.2)μ
6–septate, 2 per cent, 65 x 4.2 (54–70 x 3.9–5.2)μ
7– and 8–septate, rare, 73–81 x 4.1–4.8μ (only three measured)

Average of the above measurements:

Conidia: 0–septate, 0.6 per cent
1–septate, 4.6 per cent
2–septate, 2.2 per cent
3–septate, 14 per cent
4–septate, 4 per cent
5–septate, 40 per cent, 50 x 4.2μ
6– and 7–septate, 16.8 per cent, 76 x 4.6μ
8– and 9–septate, 14.4 per cent, 89 x 4.86μ
10– to 15–septate, 3.4 per cent, 103 x 4.9μ (the largest conidium found was 15–septate, 150 x 6μ)

22. ***Fusarium anguioides*** **var. caudatum n. var.** (Fig. 19; Pl. VI, fig. 9)
Conidial type very much the same as that of *F. anguioides*, but 8- to 11-septate conidia very rare and the size for the same septation somewhat larger; conidia never in macroscopically observable thick pseudopionnotes as is often the case in *F. anguioides* when grown on various agars. Conidia of this fungus, even in comparatively young cultures, often produce on one end a long, usually unbranched, germ tube (see certain conidia in figure 19), which has never been observed in *F. anguioides*.

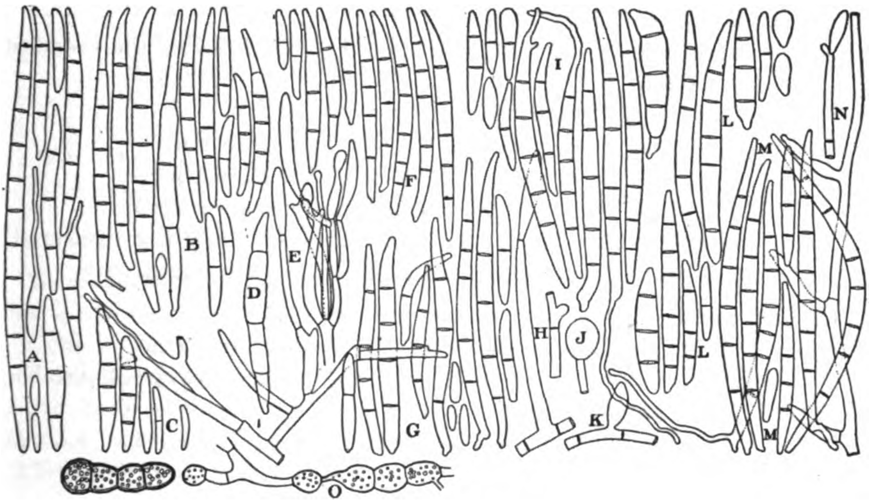

FIG. 19.—*Fusarium anguioides var. caudatum.* A, *Pseudopionnotal conidia from 10-days-old culture on slightly acidified hard potato agar;* B, *conidia from 61-days-old culture on red raspberry cane plug;* C, *typical,* D, *degenerated, conidia,* E, *conidiophores, from 67-days-old culture on potato stem plug;* F, *conidia from 15-days-old culture on wheat grain;* G, *pseudopionnotal conidia from 9-days-old culture on hard lima-bean agar;* H, *conidiophores,* I, *pseudopionnotal conidia,* J, *chlamydospore-like mycelial swelling,* K, *conidiophores, from 11-days-old culture on medium potato agar;* L, *pseudopionnotal conidia from 16-days-old culture on hard lima-bean agar with 2 per cent glucose;* M, *pseudopionnotal conidia from 37-days-old culture on hard oat agar;* N, *conidiophores from 11-days-old culture on medium potato agar*

Hab. On rotted tubers of *Solanum tuberosum*, in association with *F. coeruleum*, Ithaca, New York.

Measurements of conidia from cultures on different media are as follows:

On red raspberry cane plug, culture sixty-one days old:

Conidia: 0– and 1–septate, 10 per cent
2– to 4–septate, 35 per cent
5–septate, 55 per cent, 56 x 4.2 (35–80 x 3.7–4.8)μ
6–septate, rare, the longest 85 x 5.2μ

On hard lima-bean agar, culture sixteen days old:

Conidia: 0–septate, 17 per cent, 13 x 2.7 (11–16 x 2.3–3.7)μ
1–septate, 18 per cent, 22 x 3.3 (18–28 x 3–4.4)μ, the broadest 33 x 6.1μ
2–septate, 12 per cent
3–septate, 40 per cent, 38.5 x 4 (29–45 x 3.5–4.7)μ, the broadest 33 x 6.1μ
4–septate, 3 per cent
5–septate, 7 per cent, 60 x 4.5 (52–75 x 4.1–5.4)μ
6–septate, 3 per cent, 67 x 5.2 (53–77 x 4.1–6.1)μ
7–septate, very few, 82 x 5.2μ (only one measured)
8–septate, few, 75 x 5.3 (72–88 x 5–5.6)μ (only two measured)
9–septate, very few, 94 x 5.2μ (only one measured)

On hard potato agar, culture eleven days old:

Conidia: 0–septate, 12 per cent, 14 x 3.9 (8.7–20 x 2.6–4.2)μ
1–septate, 11 per cent, 17 x 4.1μ (only four measured)
2–septate, 9 per cent
3–septate, 47 per cent, 40 x 4.3 (25–53 x 3.5–5.3)μ
4–septate, 8 per cent
5–septate, 12 per cent, 66 x 4.6 (50–77 x 4–6.1)μ
$\left.\begin{array}{l}\text{6–septate,}\\ \text{7–septate,}\end{array}\right\}$ 1 per cent $\left\{\begin{array}{l}\text{79 x 5.3}\mu\text{ (only one measured)}\\ \text{85 x 5.2}\mu\text{ (only one measured)}\end{array}\right.$

On wheat grain, culture fifteen days old:

Conidia: 0–septate, 4 per cent
1–septate, 40 per cent, 24 x 3.1 (15–27 x 2.7–3.6)μ
2–septate, 10 per cent
3–septate, 42 per cent, 43 x 3.8 (36–62 x 3.5–5.2)μ
4–septate, 2 per cent
5–septate, 2 per cent, 55 x 4.1 (43–62 x 4–4 5)μ
6–septate, few, 57 x 4.3μ (only one measured)
7–septate, very few, 79 x 4.3μ (only one measured)

On hard lima-bean agar, culture nine days old:

Conidia: 0–septate, 14 per cent
1–septate, 28 per cent
2–septate, 5 per cent
3–septate, 32 per cent, 44 x 3.6 (29–63 x 3–4)μ (exceptionally 4.8μ in diameter)
4–septate, 5 per cent
5–septate, 16 per cent, 65 x 3.9 (52–79 x 3.5–4.8)μ

Average of the above measurements:

Conidia: 0–septate, about 10.4 per cent, 13.5 x 3.3μ
1–septate, about 20.4 per cent, 21 x 3.5μ
2–septate, about 9.2 per cent
3–septate, about 35.2 per cent, 41 x 3.9μ
4–septate, about 5.6 per cent
5–septate, about 18.4 per cent, 60.4 x 4.26μ
6– and 7–septate, about 0.8 per cent, 82 x 4.9μ
8– and 9–septate, very rare, 85 x 5.2μ

23. **Fusarium arthrosporioides** n. sp. (Figs. 1, L to P, and 20; Pl. III, figs. 3 and 4; Pl. VII, fig. 11)

Conidia of three types: (1) elliptical, apically attenuate, slightly pedicellate, mostly 5–septate, 48 x 4.3 (45–55 x 4–4.7)μ; (2) arthrosporial, 0– to 3–(5–)septate, broad spindle-shaped, 3-septate measuring about 25 x 5.4 (19–33 x 4.7–6)μ; (3) sporotrichial, mostly 0–septate, 4.5 x 3.8 (2.9–9 x 2.6–8)μ. Type 1 is found mostly in pseudopionnotes, type 2 on aërial mycelium, and type 3 mainly in small, dense, bushlike clusters of conidiophores, often resembling sporodochia; no true chlamydospores; aërial mycelium from white to light tints of rose and salmon hues, uniform or covered with knotted, more or less large, areas; substratum from clay color to buckthorn brown and bright red (Plate III, fig. 4). The organism occupies an intermediate position between sections Arthrosporiella and Sporotrichiella.

Hab. In discolored tissues of tuber of *Solanum tuberosum*, Ireland.

The organism remained for a long time in pure culture, with well-developed aërial mycelium and with a bright red color (Plate III, fig. 4); the dominant type of conidia was sickle-shaped, 5–septate. During the last year — the second year of its cultivation — the development of aërial mycelium has become poorer, the color of the substratum has changed to

clay color and buckthorn brown, and sporotrichic conidia are the commonest type. Whether the organism has changed only temporarily or not is as yet unknown.[43]

Latin description.—Conidiis tribus typis: (1) conidiis ellipticis, apice attenuatis, paulum pedicellatis, plerumque 5–septatis, 48 x 4.3 (45–55 x

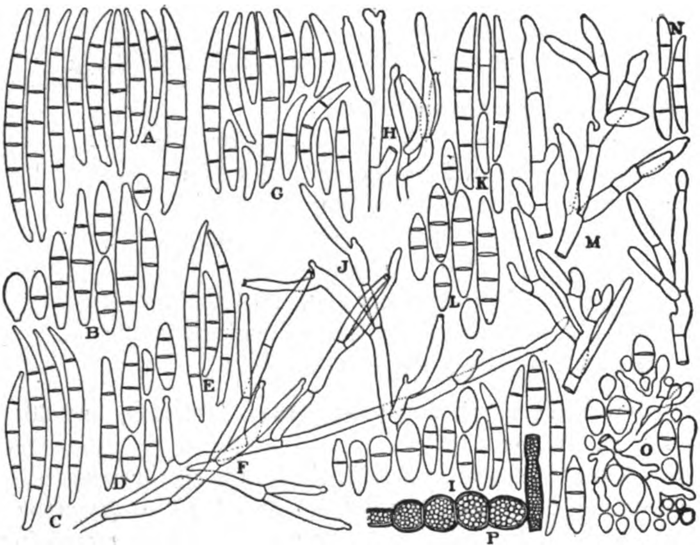

FIG. 20.—*Fusarium arthrosporioides.* A, *Normal pseudopionnotal conidia,* B, *arthrosporial conidia, from 14-days-old culture on hard lima-bean agar;* C, *sporodochial conidia from 64-days-old culture on hard lima-bean agar with 2 per cent glucose;* D, *arthrosporial,* E, *normal, conidia,* F, *conidiophores, from 11-days-old culture on medium potato agar;* G, *aërial conidia,* H, *conidiophores, from 11-days-old culture on slightly acidified hard potato agar;* I, *conidia and chlamydospores from 76-days-old culture on red raspberry cane plug;* J, *conidiophores from 11-days-old culture on medium potato agar;* K, *normal,* L, *arthrosporial, type of conidia,* M, *conidiophores, from aërial mycelium of 16-days-old culture on hard lima-bean agar with 2 per cent glucose;* N, *sickle-shaped conidia,* O, *arthrosporial and sporotrichial conidia and conidiophore of the sporodochial stage, from 36-days-old culture on rye grain;* P, *chlamydospores*

4–4.7)μ; (2) conidiis arthrosporialibus, 0–3(5)–septatis, latis fusiformibus, 3–septatis circa 25 x 5.4 (19–33 x 4.7–6)μ; (3) conidiis sporotrichialibus, plerumque 0–septatis, 4.5 x 3.8 (2.9–9 x 2.6–8)μ. Typo primo plerumque in pseudopionnotibus, typo altero in aerio mycelio, typo tertio plerumque in parvis densis fruticosis conidiophoris uveosis, saepe similibus sporodochiis; nullis veris chlamydosporis; aerio mycelio ex albo pallide roseo "salmon color" (R), uniformi vel nodosas plus minusve magnas areas

[43] In this connection see last paragraph in description of *F. biforme* (page 168).

exhibente; substrato ex argillaceo "buckthorn brown" (R) vel nitide rubro (Tab. III, fig. 4). Fungo locum medium inter Sectiones Arthrosporiellam et Sporotrichiellam obtinente.

Hab. In textibus decoloratis Solani tuberosi tuberum, Hibernia.

Measurements on different media are as follows:

On slightly acidified hard potato agar, culture eleven days old; conidia from aërial mycelium:

Conidia: 0–septate, 0.5 per cent, 12 x 2.7μ
1–septate, 15.5 per cent, 25 x 3.8 (17–30 x 2.6–4.7)μ
2–septate, 3 per cent, 27 x 4μ
3–septate, 77.5 per cent, 35 x 3.5 (22–48 x 3–4.4)μ
4–septate, 3 per cent, 43 x 4.2 (35–50 x 3.5–4.8)μ
5–septate, 0.5 per cent, 47 x 4.4μ (only a few measured)

On hard lima-bean agar with 2 per cent glucose, culture sixteen days old:

(1) Sickle-shaped conidia:
0–septate, 4.7 per cent, 10 x 2.6μ (only a few measured)
1–septate, 4.7 per cent, 19 x 3.1 (14–24 x 2.9–3.5)μ
2–septate, few, 28 x 3.3μ (only a few measured)
3–septate, 5.9 per cent, 34 x 4 (31–40 x 3.3–4.7)μ
4–septate, 0.5 per cent, 43 x 4.3 (35–44 x 4.1–4.7)μ
5–septate, 0.6 per cent, 47 x 4.4 (43–54 x 4.1–4.8)μ

(2) Arthrosporial conidia:
0–septate, 13 per cent, 8.5 x 4.3 (6–12 x 3.5–6.4)μ
1–septate, 23.5 per cent, 15 x 4.4 (9–20 x 3.5–5.3)μ
2–septate, 11.7 per cent, 18 x 5.2 (13–35 x 4.7–6)μ
3–septate, 35.4 per cent, 25 x 5.4 (19–33 x 4.7–6)μ
4–septate, few, 39 x 6 (33–47 x 5–7)μ
5–septate, few, 46 x 5.7 (42–56 x 5.2–6)μ
The largest conidium observed was 8–septate (exceptionally close-septate), and measured 58 x 6.5μ

On potato stem plug, culture one hundred and seven days old:

Conidia: 1–septate, 52 per cent, about 13 x 3.5μ
2–septate, 7 per cent
3–septate, 31 per cent, 34 x 3.4μ
4–septate, 3 per cent, 43 x 3.6μ
5–septate, 7 per cent, 45 x 4 (40–50 x 3.4–4.3)μ

On hard lima-bean agar, culture sixty-four days old; conidia from a sporodochium:

Conidia: 1–septate, 1 per cent
3–septate, 12 per cent, 26 x 3.4 (22–44 x 3–3.6)μ
4–septate, 5 per cent, 43 x 3.9μ (only two measured)
5–septate, 81 per cent, 48 x 4 (43–52 x 3.5–4.3)μ
6–septate, 1 per cent, about 50 x 4.1μ (only two measured)

On hard lima-bean agar, culture fourteen days old; conidia from a dense mycelial growth at the bottom of the slant:

Conidia: 0–septate, 1.5 per cent, 13 x 4.8μ (only three measured)
1–septate, 10 per cent, 20 x 5.2 (9–27 x 4.1–7)μ
2–septate, 4 per cent, 22 x 8.3μ (only three measured)
3–septate, 38 per cent, 28 x 5.2 (19–39 x 4.3–5.9)μ
4–septate, 4 per cent
5–septate, 37 per cent, 55 x 4.7 (43–70 x 4.4–5.3)μ
6–septate, 4 per cent, 61 x 5 (54–70 x 4.8–5.3)μ
7–septate, 1.5 per cent, 69 x 5 (64–79 x 4.7–5.3)μ

On rye grain, culture thirty-six days old; conidia from a sporodochium, of sporotrichial type:

Conidia: 0–septate, 97 per cent, 4.5 x 3.8 (2.9–9 x 2.6–8)μ
1–septate, 3 per cent, 10.2 x 5.6 (8.5–14 x 4.2–6.3)μ
2–septate, rare
3–septate, rare

Average of the above measurements:

Conidia: 0–septate, 17 per cent $\begin{cases} 4.5 \text{ x } 3.8\mu \text{ (sporotrichial form)} \\ 12.1 \text{ x } 3.8\mu \text{ (arthrosporial form)} \end{cases}$
1–septate, 18 per cent, 17 x 14.2μ
2–septate, 6 per cent
3–septate, 33 per cent, 25 x 5.4μ (arthrosporial form)

4–septate, 3 per cent
5–septate, 21 per cent, 48 x 4.3μ (sickle-shaped)
6–septate, 1 per cent, 55.5 x 4.55μ (sickle-shaped)
7–septate, 0.5 per cent, 69 x 5μ (sickle-shaped)

In the case of this organism, the average percentage of septation of conidia is of no value because of the great diversity of the forms occurring. Therefore it is a safer basis to consider each stage (sporodochial and from aërial mycelium) by itself separately.

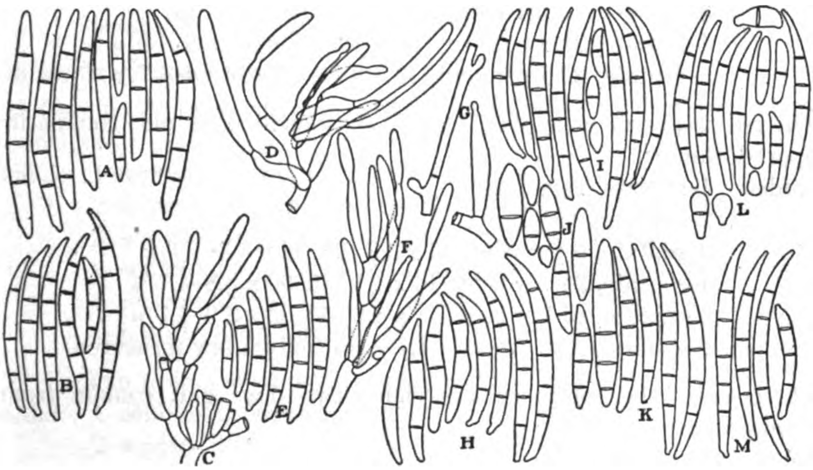

FIG. 21.—*Fusarium arthrosporioides var. asporotrichius.* A, *Aërial conidia from 7-days-old culture on hard lima-bean agar with 2 per cent glucose;* B, *sporodochial conidia from 82-days-old culture on potato tuber plug;* C, D, *conidiophores, from 11-days-old culture on slightly acidified hard potato agar;* E, *aërial conidia from 25-days-old culture on potato tuber plug;* F *and* G, *conidiophores,* H, *pseudopionnotal conidia, from 11-days-old culture on slightly acidified hard potato agar;* I, *conidia from 68-days-old culture on red raspberry cane plug;* J, *arthrosporium-like,* K, *normal, conidia from aërial mycelium from 14-days-old culture on hard lima-bean agar;* L, *aërial conidia from 36-days-old culture on rye grain;* M, *sporodochial conidia from 14-days-old culture on hard lima-bean agar*

24. *Fusarium arthrosporioides* var. **asporotrichius** n. var. (Figs. 1, R and S, and 21; Pl. VII, fig. 9)

This fungus is very much the same as *F. arthrosporioides*, but differs from the latter by typical absence of sporotrichial sporodochia and by more pronounced and common production of from medium to large (up to 3 millimeters in diameter) sporodochia with sickle-shaped, 5–septate conidia, 51.2 x 4.3 (46–59 x 4.15–4.7)μ, as dominant type.

Hab. On rotted tubers of *Solanum tuberosum* in association with *F. Solani* and *F. coeruleum*, New York State.

Measurements on different media are as follows:

On slightly acidified hard potato agar, culture eleven days old, conidia from pseudopionnotes:

Conidia: 0–septate, 0.8 per cent
1–septate, 3.4 per cent, 20 x 3.3μ
2–septate, 2.5 per cent, 30 x 3.8μ
3–septate, 49 per cent, 40 x 4 (30–56 x 3–4.7)μ
4–septate, 21.8 per cent, 50 x 4.3 (43–60 x 3.9–4.5)μ
5–septate, 22.5 per cent, 53.5 x 4.4 (49–62 x 4–4.7)μ

On red raspberry cane plug, culture sixty-eight days old; conidia from a sporodochium:

Conidia: 1–septate, very rare
2–septate, very rare
3–septate, 9 per cent, 41 x 3.7 (21–48 x 3.3–4.4)μ
4–septate, 24 per cent, 46 x 4.1 (36–60 x 3.8–4.7)μ
5–septate, 67 per cent, 51 x 4.2 (42–62 x 3.9–4.7)μ
6–septate, rare, 62–70 x 4.1–4.8μ (only a few measured)

On potato tuber plug, culture eighty-two days old; conidia from a sporodochium:

Conidia: 1–septate, rare
2–septate, rare
3–septate, 6 per cent, 36 x 3.8 (25–42 x 3.5–4.1)μ
4–septate, 17 per cent
5–septate, 77 per cent, 49 x 4.2 (43–55 x 3.5–4.7)μ

On hard lima-bean agar, culture seven days old; conidia from aërial mycelium:

Conidia: 0–septate, 3 per cent
1–septate, 8 per cent
2–septate, 8 per cent
3–septate, 65 per cent, 39 x 4.1 (31–67 x 3.9–5.7)μ, the longest 68 x 4.4μ
4–septate, 14 per cent, 49 x 4.7 (44–60 x 4.2–5.3)μ
5–septate, 2 per cent, 59 x 4.8 (52–63 x 4.3–5.7)μ

On potato tuber plug, culture twenty-five days old; conidia from aërial mycelium:

Conidia: 0–septate, rare, about 16 x 2.5μ
1–septate, 7 per cent, 22 x 3.7μ (only three measured)
2–septate, 6 per cent, 27 x 4.1μ (only three measured)
3–septate, 40 per cent, 35 x 4.3 (29–45 x 3.8–4.8)μ
4–septate, 28 per cent, 43 x 4.7 (35 x 49 x 4.1–5.2)μ, the broadest 51 x 5.9μ
5–septate, 19 per cent, 45 x 4.7 (40–53 x 4.3–4.9)μ
6–septate, only one observed, 78 x 5.2μ

On whole steamed potato tuber, culture forty-six days old:

(1) Conidia from a medium large (2 millimeters in diameter) sporodochium

Conidia: 1–septate, 2.5 per cent, about 16 x 3μ
2–septate, 2.5 per cent, about 28 x 3.5 (20–40 x 3.3–3.8)μ
3–septate, 31 per cent, 38.5 x 3.7 (19–44 x 3–4.1)μ
4–septate, 34 per cent, 45 x 4μ (only three measured)
5–septate, 30 per cent, 48 x 4.15 (44–53 x 3.9–4.7)μ
6–septate, very rare, 61 x 4.3μ (only one measured)

(2) Conidia from a small sporodochium

Conidia: 1–septate, 2 per cent
2–septate, rare
3–septate, 51 per cent, 40 x 3.9 (35–43 x 3–4.1)μ
4–septate, 24 per cent, 42 x 4.1 (36–50 x 3.5–4.8)μ
5–septate, 23 per cent, 46 x 4.2 (42–50 x 4–4.5)μ

On medium potato agar, culture eleven days old; conidia from pseudopionnotes:

Conidia: 3–septate, 13 per cent, 39 x 4.3 (28–48 x 3.5–4.8)μ
4–septate, 8 per cent
5–septate, 79 per cent, 48 x 4.6 (41–61 x 3.8–4.9)μ

On hard lima-bean agar, culture fourteen days old:

(1) Conidia from aërial mycelium

Conidia: 0–septate, 6 per cent, 11 x 4.6 (6–18 x 4–5.3)μ
1–septate, 13 per cent, 18 x 5 (10–25 x 4.1–5.5)μ

2–septate, 10 per cent, 24 x 5.1 (20–30 x 4.3–5.5)μ (only three measured)
3–septate, 39 per cent, 31 x 5.2 (22–43 x 4.1–6.2)μ
4–septate, 7 per cent
5–septate, 25 per cent, 56 x 4.7 (42–70 x 4–5.9)μ
6–septate, very few, 63 x 4.9μ (only one measured)

(2) Conidia from a sporodochium
Conidia: 3–septate, about 5 per cent, 36 x 3.1μ (only a few measured)
4–septate, about 5 per cent
5–septate, about 90 per cent, 58 x 4 (52–65 x 3.5–4.8)μ

On rye grain, culture thirty-six days old:
Conidia: 0–septate, 3 per cent
1–septate, 6 per cent
2–septate, 2 per cent
3–septate, 55 per cent, 38 x 3.4 (27–50 x 3–4.4)μ
4–septate, 20 per cent
5–septate, 14 per cent, 50 x 3.6 (43–60 x 3.1–4.4)μ

Average of the above measurements:
Conidia: 0–septate, 1 per cent
1–septate, 3 per cent
2–septate, 3 per cent
3–septate, 33 per cent
4–septate, 19 per cent
5–septate, 41 per cent, 51.2 x 4.3μ
6–septate, very rare

25. *Fusarium diplosporum* Cke. et Ell.

Cf. Cooke, M. C., and Ellis, J. B., Grevillea 7:38. 1878. Saccardo, Syll. Fung. 4:701. 1886.

The following description is from Saccardo:

"Roseum, pulvinatum; conidiis aliis fusiformibus, utrinque acutis, arcuatis, nucleatis, demum leniter 3–septatis 40μ long., aliis ellipticis, uniseptatis 18 x 8μ.

"Hab. In caulibus Solani tuberosi, New Jersey, Amer. bor."

The abbreviated, arthrosporial, uniseptate, conidia, 18 x 8μ in size, are so uncommon that there is no doubt in the writer's mind that the

organism could easily be identified when found, and thus must be recognized as a good species. The organism was not isolated by the writer.

VII. SECTION SPOROTRICHIELLA Wr. (Fig. 1Q). Wollenweber, H. W., Maine Agr. Exp. Sta., Bul. 219:256. 1913

Fusaria of this section have from pyriform to nearly globular, mostly 0–septate, microconidia. Typical sickle-shaped, septate conidia always present, at least in young artificial cultures.

Only one species of this section is presented here. This species was twice isolated from rotted potato tubers, and thus, at least in a way, may be considered as of more or less common occurrence on this substratum. There are many other Fusaria of this section reported on such substrata as corn, carnations, apples, and others, a number of which are discussed by Lewis (1913). None of the species of this section mentioned by him, however, seem to be identical with the one here reported.

Lewis (1913:257) reports that the following organisms were isolated also from potatoes: (1) *F. Poae* (Peck) Wr., (2) *F. Solani* (Mart.) Ap. et Wr., (3) *F. conglutinans* Wr., (4) *F. Helianthi* Sacc. var., (5) *F. pirinum* (Fries) Sacc., and (6) *F. orthoceras* Ap. et Wr.

Numbers 2 and 6 are described in this paper; numbers 1 and 4 are closely related to *F. sporotrichioides* n. sp., and belong to section Sporotrichiella; number 3 belongs to section Elegans and differs from *F. orthoceras* by absence of red-wine color on rice (see Wollenweber, 1913 a:30); number 5 may belong to section Arthrosporiella.

No technical description, except results of inoculations—for potatoes always negative—and certain characters of color and of colony growth, is given, and thus a proper identification is rendered impracticable.

26. **Fusarium sporotrichioides** n. sp. (Figs. 1Q and 22; Pl. III, fig. 1)

Conidia scattered in aërial mycelium or in pseudopionnotes and distinct sporodochia; of diverse type, ranging from unicellular, more or less pyriform, microconidia of sporotrichial form, to sickle-shaped, 3– to 10–septate, apically pointed, pedicellate, macroconidia; 0–septate, sporotrichial conidia average 10.5 x 6 (9.5–11.4 x 5.6–6.5)μ; sickle-shaped, 3–septate conidia average 30.4 x 3.8μ, and 5–septate average 50.5 x 4.3μ; conidia of pseudopionnotes stage resemble those of *F. anguioides*; chlamydospores often present, intercalary, commonly in small clusters;

color of aërial mycelium and of substratum from white to clay (Pl. III, fig. 1) and pink, similar to the color of *F. bullatum* var. *roseum* (Pl. III, fig. 2).

Hab. On rotted tubers of *Solanum tuberosum*, together with *F. Solani* and *F. oxysporum*, New York State.

Latin description.—Conidiis in aerio mycelio sparsis vel in pseudopionnotibus et sporodochiis distinctis; typis variis: interdum microconidiis unicellularibus, plus minusve pyriformibus, sporotrichialibus; interdum

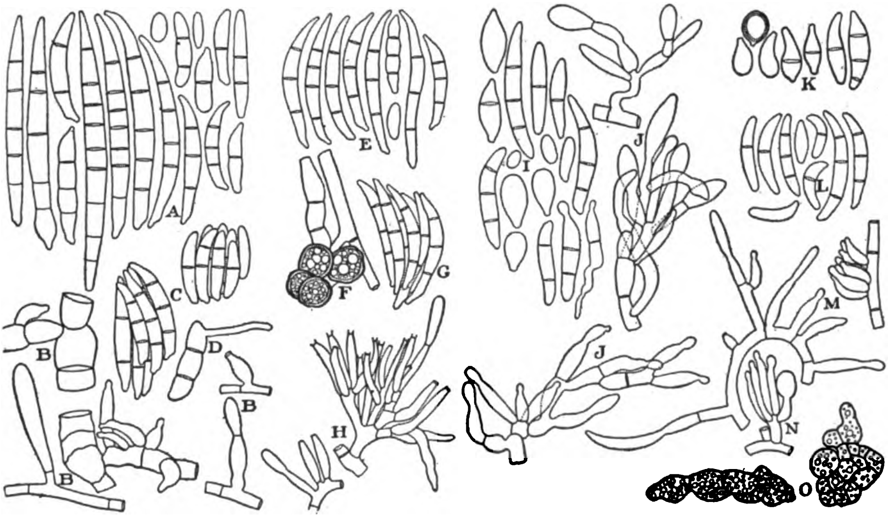

FIG. 22.—*Fusarium sporotrichioides.* A, *Pseudopionnotal conidia,* B, *various simple conidiophores,* C, *balls of conidia,* D, *germinating conidium, from 5-days-old culture on hard potato agar;* E, *sporodochial conidia,* F, *chlamydospores,* G, *ball of conidia,* H, *compound conidiophores, from 86-days-old culture on hard potato agar;* I, *sporotrichial conidia (some germinating),* J, *conidiophores, from aërial mycelium of 16-days-old culture on wheat grain;* K, *typical, thick-walled sporotrichial conidia,* L, *sickle-shaped conidia,* M, *conidiophores producing sickle-shaped conidia,* N, *conidiophore producing sporotrichial conidia,* O, *plectenchymic stroma, from 52-days-old culture on red raspberry cane plug*

macroconidiis falciformibus, 3–10–septatis, apice acutis, pedicellatis; conidiis 0–septatis sporotrichialibus plerumque 10.5 x 6 (9.5–11.4 x 5.6–6.5)μ; falciformibus, 3–septatis 30.4 x 3.8μ, et 5–septatis 50.5 x 4.3μ; conidiis pseudopionnotum gradu similibus conidiis F. anguioidum; chlamydosporis saepe visis, intercalaribus, plerumque minutis uveosis; aerio mycelio substratoque ex albo argillaceo vel rubello, simili colore F. bullati rosei.

Hab. In tuberibus putridis Solani tuberosi una cum F. Solani et F. oxysporo, New York, Amer. bor.

Measurements of conidia on different media are as follows:

On slightly acidified hard potato agar, culture five days old; conidia from pseudopionnotes:

Conidia: 0–septate, 2 per cent
1–septate, 10.5 per cent, 19 x 3.5μ
2–septate, 5.5 per cent, 28 x 3.7μ
3–septate, 37 per cent, 32.5 x 4.2 (24–50 x 3.9–4.7)μ
4–septate, 6 per cent, 45 x 4.2μ
5–septate, 33 per cent, 48 x 4.5 (40–62 x 3.9–5.3)μ
6– to 10–septate, 6 per cent, 50–90 x 5–6.1μ

On hard potato agar, culture eighty-six days old; conidia from a small sporodochium, semi-dry:

Conidia: 3–septate, nearly 100 per cent, 29.5 x 3.4 (20–41 x 3–4)μ

On red raspberry cane plug, culture fifty-two days old:

(1) Conidia of sporotrichial form

Conidia: 0–septate, 97 per cent, 9.5 x 6.5 (7–12 x 4–7.5)μ
1–septate, 3 per cent, 13.5 x 5.2 (10–15 x 4.8–6)μ
2–septate, rare
3–septate, exceptional, one measured, 21 x 5.2μ

(2) Conidia of sickle-shaped form

Conidia: 0–septate, 35 per cent, 11 x 2.9 (10–13 x 2.5–3.1)μ
1–septate, 60 per cent, 15.5 x 3.2 (12–22 x 2.9–3.5)μ
2–septate, very rare
3–septate, 5 per cent, 25 x 3.5 (20–28 x 3–4)μ

On hard lima-bean agar with 2 per cent glucose, culture 10 days old; conidia from a pseudopionnotes:

Conidia: 0–septate, 5 per cent, 10 x 3 (5.2–16 x 2.1–3.7)μ
1–septate, 15 per cent, 22 x 3.3 (16–28 x 3–3.5)μ
2–septate, 2 per cent
3–septate, 22 per cent, 33 x 3.8 (27–49 x 3.5–4.8)μ
4–septate, 23 per cent, 45 x 4 (38–49 x 3.9–4.1)μ
5–septate, 30 per cent, 51 x 4.1 (41–62 x 3.5–4.7)μ

6–septate, 1.5 per cent, 65 x 4.1 (60–80 x 3.7–4.4)μ (only four measured)

7–septate, 1.5 per cent, 67 x 4.5 (62–72 x 4.1–5.3)μ (only four measured)

On wheat grain culture sixteen days old; conidia from aërial mycelium:

(1) Sporotrichial form

Conidia: 0–septate, 70 per cent, 11.4 x 5.6 (8–16 x 4–6.5)μ

1–septate, 30 per cent, 14 x 5.6 (11–17 x 4.8–6)μ

(2) Sickle-shaped form

Conidia: 0–septate, 9 per cent, 10 x 3.2μ

1–septate, 68 per cent, 20 x 3.8 (12–24 x 3–4.2)μ

2–septate, 5 per cent

3–septate, 18 per cent, 32 x 4.3 (24–44 x 3.9–4.7)μ

Average of the above measurements:

(1) Sporotrichial form

Conidia: 0–septate, 83 per cent, 10.5 x 6μ

1–septate, 17 per cent, 14 x 5.4μ

2– and 3–septate, rare to very rare

(2) Sickle-shaped form

Conidia: 0–septate, 10 per cent

1–septate, 31 per cent, 10 x 3.1μ

2–septate, 2 per cent

3–septate, 36 per cent, 30.4 x 3.8μ

4–septate, 6 per cent

5–septate, 13 per cent, 50.5 x 4.3μ

6– to 10–septate, 2 per cent, about 67 x 4.5μ

VIII. Section **Ferruginosum** n. sec.

Conidia mostly of an intermediate type, between that of section Gibbosum and section Roseum, 3– to 7–septate; intercalary chlamydospores typically present. Substratum and basal layer of aërial mycelium varying from white when young to different hues of red at maturity.

27. **Fusarium arcuosporum** n. sp. (Figs. 1B₁ and 23; Pl. II, figs. 7 and 8; Pl. VI, fig. 10)

Conidia very gradually pointed toward apex, distinctly and often

prominently pedicellate, typically much arcuate, 5-septate, 49.2 x 4 (42–54 x 3.6–4.2)μ, also often from 3- to 7-septate; single on aërial conidiophores and in from small to medium (up to 1.5 millimeters in diameter) sporodochia, the latter sometimes converging into pseudopionnotes; intercalary chlamydospores in mycelial threads typically present, though not numerous, and single or only in small clusters of from two to four cells; aërial mycelium usually well developed, uniform, white at first, then, on substrata poor in glucose, of different tints of pink with the substratum of a pomegranate color of different density; on potato agar rich in glucose, color as shown in Plate II, figures 7 and 8.

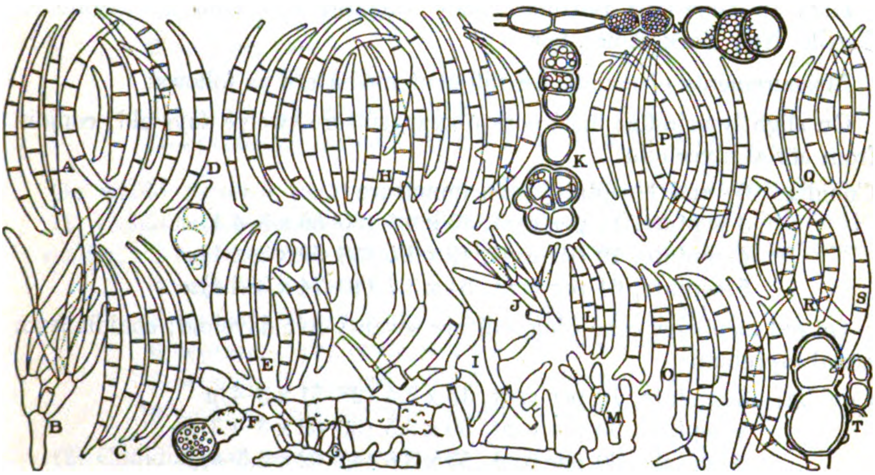

FIG. 23.—*Fusarium arcuosporum.* A, *Sporodochial conidia,* B, *conidiophore, from 20-days-old culture on hard lima-bean agar with 2 per cent glucose;* C, *conidia from small aërial sporodochium from 49-days-old culture on whole steamed potato tuber;* D, *typical conidium (the long one) and abnormal pseudopionnotal conidium from 11-days-old hard potato agar;* E, *aërial conidia,* F, *chlamydospores,* G, *conidiophores, from 75-days-old culture on red raspberry cane plug;* H, *pseudopionnotal conidia,* I, *conidiophores, from 12-days-old culture on slightly acidified hard potato agar;* J, *conidiophore,* K, *chlamydospores,* L, *conidial ball,* M, *conidiophores, from aërial mycelium from 75-days-old culture on red raspberry cane plug;* N, *chlamydospores from 173-days-old culture on corn agar;* O, *peculiarly branched,* P, *normal, pseudopionnotal conidia from 14-days-old culture on hard lima-bean agar;* Q, *conidia from aërial sporodochium of 107-days-old culture on potato stem plug;* R, *conidia from 109-days-old culture on rye straw;* S, *typical sporodochial conidium from 24-days-old culture on potato tuber plug;* T, *chlamydospores from 109-days-old culture on rye straw*

Hab. On rotted tubers of *Solanum tuberosum,* in association with *F. anguioides,* Castile, New York.

Latin description.—Conidiis maxime gradatim in apicem acutis, distincte vel saepe insignite pedicellatis, typice magnopere arcuatis, 5–septatis, 49.2 x 4 (42–54 x 3.6–4.2)μ, etiam saepe 3–7–septatis; continuis in aeriis conidiophoris vel minutis mediocribusve (usque ad $\frac{1}{5}$ mm. diam.) sporodochiis in pseudopionnotes interdum vergentibus; chlamydosporis intercalaribus sed non plurimis, continuis vel tantum minutis uveosis, 1–3–septatis; aerio mycelio fere plene maturo, uniformi, primum albo, dein, in substratis parum glucosis, rubello varie tincto, substrato "pomegranate" (R); in Solani tuberosi agare perglucoso, colore Tab. II, figg. 7, 8, exhibito.

Hab. In tuberibus putridis Solani tuberosi una cum F. anguioide, Castile, New York, Amer. bor.

Measurements of conidia on different media are as follows:

On slightly acidified hard potato agar, culture twelve days old; conidia from aërial mycelium:

Conidia: 0– and 1–septate, rare, immature
3–septate, 17 per cent, 43 x 3.5 (35–56 x 3–4.1)μ
4–septate, 19 per cent, 49 x 3.5 (38–59 x 3–4.1)μ
5–septate, 64 per cent, 54 x 3.7 (40–74 x 3–4.4)μ

On red raspberry cane plug, culture seventy-five days old; conidia from aërial mycelium:

Conidia: 3–septate, 10 per cent, 45 x 3.4 (28–51 x 3–4)μ
4–septate, 30 per cent, 50 x 3.5 (36–62 x 3–4.3)μ
5–septate, 60 per cent, 53 x 3.6 (44–62 x 3.5–4)μ

On hard lima-bean agar with 2 per cent glucose, culture seven days old; conidia from aërial mycelium:

Conidia: 3–septate, 30 per cent (granulation of the protoplasm was too
4–septate, 15 per cent great to clearly distinguish septation)
5–septate, 55 per cent, 53 x 3.8 (45–62 x 3.4–4.4)μ

On hard lima-bean agar with 2 per cent glucose, culture twenty days old; conidia from pseudopionnotes:

Conidia: 0–septate, rare
1–septate, rare
4–septate, 4 per cent, 47 x 4.2μ (only two measured)
5–septate, 95 per cent, 54 x 4 (47–63 x 3.5–4.8)μ
6–septate, 1 per cent, 52 x 4.1μ (only two measured)

On potato tuber plug, culture twenty-four days old; conidia from small sporodochia:

Conidia: 1–septate, 1 per cent, about 14 x 3.5μ (only one measured)
3–septate, 10 per cent, 35 x 3.6 (27–43 x 3–4.4)μ
4–septate, 12 per cent
5–septate, 77 per cent, 45 x 4 (35–51 x 3.3–4.8)μ
6– and 7–septate, rare, 52 x 4.5μ (only two measured)

On potato stem plug, culture one hundred and seven days old; conidia from aërial mycelium:

Conidia: 0–septate, rare
1–septate, 2 per cent
2–septate, rare
3–septate, 50 per cent, 31 x 3.7μ
4–septate, 25 per cent, 40 x 4μ
5–septate, 23 per cent, 42 x 4.2 (35–48 x 3.9–4.7)μ

On whole steamed potato tubers, culture forty-nine days old:

(1) Conidia from numerous small sporodochia, close to the substratum

Conidia: 3–septate, 6 per cent, about 30 x 3.5 (only a few spores measured)
4–septate, 6 per cent
5–septate, 80 per cent, 46 x 4.1 (40–53 x 3.9–4.1)μ
6–septate, 5 per cent, 54 x 4.1 (42–65 x 4–4.7)μ
7–septate, 3 per cent, 59 x 4.2 (48–65 x 4.1–4.5)μ
10–septate, only one was observed, 58 x 4.3μ (the largest)

(2) Conidia from small sporodochia, in aërial mycelium

Conidia: 3–septate, rare
4–septate, rare
5–septate, nearly 100 per cent, 51 x 4 (45–55 x 3.6–4.3)μ
6–septate, rare

On medium soft agar, culture eleven days old; conidia from aërial mycelium close to substratum:

Conidia: 1–septate, 2 per cent, 24 x 3.2 (only a few measured)
3–septate, 8 per cent, 42 x 4μ (only a few measured)
4–septate, 10 per cent
5–septate, 77 per cent, 45 x 4.1 (41–62 x 3.1–4.8)μ
6–septate, 3 per cent, 49 x 4.3μ (only a few measured)

On hard lima-bean agar, culture fourteen days old; conidia from minute converging sporodochia close to substratum:

Conidia: 3–septate, 3 per cent
4–septate, 1 per cent
5–septate, 95 per cent, 49 x 4.2 (41–63 x 3.5–5.3)μ
6–septate, 1 per cent, 54 x 4.7μ (only a few measured)

Average of the above measurements:

Conidia: 0– to 2–septate, very rare
3–septate, 13 per cent, 38 x 3.5μ
4–septate, 13.5 per cent
5–septate, 72.5 per cent, 49.2 x 4μ
6– and 7–septate, 1 per cent, 53.6 x 4.3μ

The organism occupies an intermediate position between section Roseum and section Ferruginosum; its type of conidia is that of section Roseum, while because of its true chlamydospores of only an intercalary kind it belongs to the section Ferruginosum.

An especially striking peculiarity of *F. arcuosporum* is the frequent occurrence, especially in young cultures on various agars, of conidia with more or less distinct branches and knobs (Fig. 23 o).

28. **Fusarium ferruginosum** n. sp. (Figs. 1, H to J, and 24; Pl. III, figs. 9 and 10; Pl. VI, fig. 2)

Conidia well developed, in from small to medium-sized (up to 2 millimeters in diameter) sporodochia or in pseudopionnotes, very gradually pointed toward apex, distinctly pedicellate, more or less strongly arcuate, and broader in the middle or in the lower third of their length, typically 3– to 5–septate; 5–septate average 45.3 x 4.2 (28–53 x 4.1–4.2)μ; conidia from aërial mycelium — sometimes also from sporodochia produced on very old agar cultures — typically 3–septate, 30.8 x 3.8μ, mostly apedicellate; conidia from nearly white to pale pink buff and deep vinaceous in color; intercalary chlamydospores in mycelium always present, often very numerous, in long chains and large clusters; aërial mycelium always well developed, high, often very dense, white at first changing to pink and then ferruginous when mature, the last-named color being due to production of great masses of chlamydospores; color of substratum, on

potato agar rich in glucose, at first pink, then ochraceous tawny, and finally ferruginous and Hay's russet.

Hab. On rotted tubers of *Solanum tuberosum*, Long Island, New York, on *Lycopersicum esculentum*, Virginia, and on *Panax quinquefolium*, New York State.

Latin description.—Conidiis plene maturis—sporodochiis minutis vel mediocribus (usque ad 2 mm. diam.) vel pseudopionnotibus—maxime gradatim in apicem acutis, distincte pedicellatis, plus minusve valide arcuatis, latioribus in medio vel in inferiore tertio longitudinis, typice 3–5-septatis; 5-septatis plerumque 45.3 x 4.2 (28–53 x 4.1–4.2)μ; conidiis in aerio mycelio—interdum etiam ex sporodochiis in vetustissimis agaris

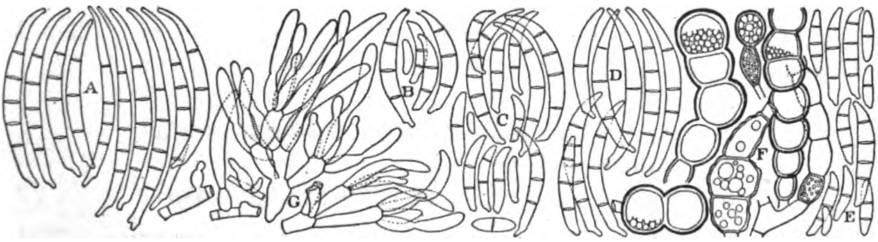

FIG. 24.—*Fusarium ferruginosum.* A, *Pseudopionnotal conidia from 10-days-old culture on hard lima-bean agar;* B, *sporodochial conidia from 130-days-old culture on hard lima-bean agar with 2 per cent glucose;* C, *aërial conidia from 14-days-old culture on slightly acidified hard potato agar;* D, *pseudopionnotal conidia from 3-days-old culture on hard lima-bean agar;* E, *aërial conidia,* F, *chlamydospores, from 35-days-old culture on corn meal;* G, *conidiophores from 3-days-old culture on hard lima-bean agar*

culturis crescentibus—typice 3-septatis, 30.8 x 3.8μ, plerumque apedicellatis; conidiis ex albido pallide rubellis, gilvis atque vinaceosis; chlamydosporis intercalaribus semper in mycelio praesentibus, saepe plurimis, longis catenulatis longis uveosisque; aerio mycelio semper plene maturo, alto, semper densissimo, primum albo, dein rubello demum ferrugineo, quem colorem magnae moles chlamydosporum ortae efficiunt; substrato in agare Solani tuberosi glucoso, primum rubello, dein "ochraceous tawny" (R), demum ferrugineo et "Hay's russet" (R).

Hab. In tuberibus putridis Solani tuberosi, Long Island, New York, in Lycopersico esculento, Virginia, et in Panaci quinquefolio, New York, Amer. bor.

Measurements of conidia on different media are as follows:

On hard lima-bean agar with 2 per cent glucose, culture one hundred and thirty days old; conidia from small sporodochia produced after the culture was over eighty days old:

Conidia: 0–septate, very rare, 9 x 2.8μ
1–septate, 4 per cent, 12 x 3.2μ
2–septate, 3 per cent, 17 x 3.5μ
3–septate, 93 per cent, 27.3 x 4.1 (17–33 x 3.8–4.4)μ

On hard potato agar with 10 per cent glucose, culture seven days old in poured plate:

(1) Chlamydospores
0–septate, 10 x 9.5 (7–12.5 x 7–11.5)μ
1–septate, 16 x 11μ

(2) Conidia from aërial mycelium

Conidia: 1–septate, 1 per cent
2–septate, 1 per cent
3–septate, 88 per cent, 32 x 3.7 (25–40 x 3.1–4.2)μ
4–septate, 6 per cent
5–septate, 4 per cent, 38 x 4.1 (35–42 x 3.9–4.4)μ

On hard lima-bean agar, culture three days old; conidia from pseudopionnotes (near the center of inoculation):

Conidia: 3–septate, 66 per cent, 36 x 3.9 (30–41 x 3.5–4.3)μ
4–septate, 20 per cent
5–septate, 14 per cent, 45 x 4.2 (42–56 x 3.9–4.7)μ

On corn meal agar, culture thirty-five days old:

(1) Chlamydospores typically in chains, 8.5 (5.8–15)μ in diameter

(2) Conidia from aërial mycelium

Conidia: 0–septate, 20 per cent, 8.8 x 2.6 (7–12 x 2.4–3)μ
1–septate, 46 per cent, 12.8 x 2.9 (9–19 x 2.5–3.1)μ
2–septate, 6 per cent
3–septate, 26 per cent, 20.4 x 3.4 (17–30 x 3–3.8)μ
4–septate, 2 per cent, 26.7 x 3.9 (24–29 x 3.7–4)μ

On hard lima-bean agar, culture ten days old; conidia from pseudopionnotes:

Conidia: 3–septate, 8 per cent, 41 x 3.9μ
4–septate, 12 per cent, 45.5 x 4μ

5–septate, 80 per cent, 53 x 4.2 (50–58 x 4.1–4.4)μ, the largest observed being 65 x 4.1μ

On slightly acidified hard potato agar, culture fourteen days old; conidia from aërial mycelium:

Conidia: 0–septate, 26 per cent, 10 x 2.5 (8–14 x 1.7–3.5)μ
1–septate, 41.5 per cent, 17.3 x 3 (14–20 x 2.5–3.5)μ
2–septate, 10 per cent, 19.5 x 3.2 (15–31 x 2.9–4)μ
3–septate, 17.5 per cent, 28 x 3.6 (19–42 x 2.9–4.7)μ
4–septate, 3 per cent } 38 x 4.2 (30–45 x 3.9–5.2)μ
5–septate, 2 per cent }

Average of the above measurements:

Conidia: 0–septate, 7.5 per cent, 9.4 x 2.55μ
1–septate, 14.5 per cent, 13 x 3μ
2–septate, 3 per cent
3–septate, 48 per cent, 30.8 x 3.8μ
4–septate, 10 per cent, 38.8 x 4.03μ
5–septate, 17 per cent, 45.3 x 4.2μ

The organism was isolated only once from potato tubers, but it was isolated by the writer from a specimen of Rhizoctonia-infected tomato plant also, from Virginia, and by C. O. Dalrymple from ginseng garden soil in New York State. This seems to be a cosmopolitan species.

29. **Fusarium sanguineum** n. sp. (Fig. 25; Pl. III, figs. 7 and 8; Pl. VI, fig. 1)

Conidia typically strongly arcuate, gradually pointed toward apex, distinctly pedicellate, 3– to 5–septate — 3–septate conidia averaging 33.5 x 3.6 (24–37 x 3.4–3.8)μ and 5–septate averaging 45.2 x 4.1 (40–47 x 3.9–4.2)μ — single, in from small to medium-sized (up to 2 millimeters in diameter) sporodochia and in pseudopionnotes, the latter form of fructification dominant on most media, especially on agars; chlamydospores almost always present, intercalary in conidia and in mycelial threads, borne singly, in chains and in clusters; aërial mycelium seldom well developed and then from white to different shades of pink, on various agars mostly absent leaving exposed pseudopionnotes of ox-blood red color.

Hab. On rotted tubers of *Solanum tuberosum* in association with *F. lutulatum* var. *zonatum*, Ithaca, New York.

Latin description.—Conidiis typice valide arcuatis, gradatim in apicem acutis, distincte pedicellatis, 3–5-septatis — conidiis 3-septatis, 33.5 x 3.6 (24–37 x 3.4–3.8)μ, conidiis 5-septatis, 45.2 x 4.1 (40–47 x 3.9–4.2)μ — continuis, minutis vel mediocribus (usque ad 2 mm. diam.) sporodochiis et pseudopionnotibus, quo fructificationis modo in plurimis mediis frequentissimo imprimis in agaribus; chlamydosporis plerumque praesentibus, intercalaribus in conidiis et in hyphis, singulatim ortis, catenulatis vel uveosis; aerio mycelio raro plene maturo, sed, cum plene maturum, tum

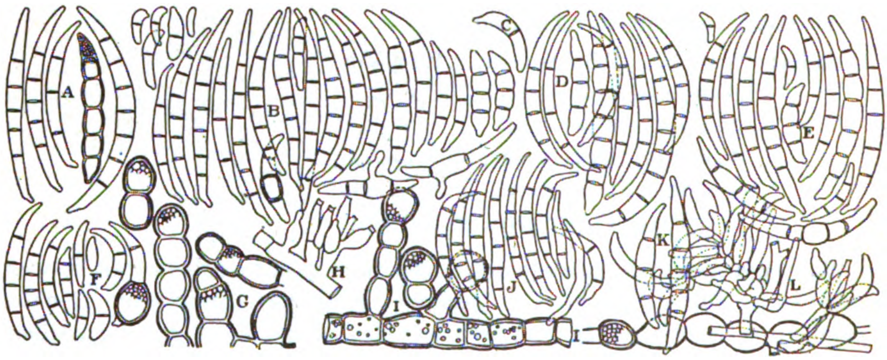

FIG. 25.— *Fusarium sanguineum.* A, *Pseudopionnotal conidia (one chlamydospore-like conidium) from 8-days-old culture on hard lima-bean agar with 2 per cent glucose;* B, *pseudopionnotal conidia from 14-days-old culture on hard lima-bean agar;* C, *typical conidium from 47-days-old culture on whole grains of wheat;* D, *pseudopionnotal conidia from 19-days-old culture on slightly acidified hard potato agar;* E, *pseudopionnotal conidia from 23-days-old culture on red raspberry cane plug;* F, *conidia,* G, *chlamydospores, from 76-days-old culture on potato tuber plug;* H, *conidiophores from 23-days-old culture on red raspberry cane plug;* I, *chlamydospores from 176-days-old culture on corn agar;* J, *sporodochial conidia from 41-days-old culture on rye straw;* K, *conidia from 176-days-old culture on corn meal;* L, *conidiophores from 47-days-old culture on whole grains of wheat*

ex albo varie rubello tincto, in agaribus variis plerumque absente, pseudopionnotes "ox-blood red" (R) exponente.

Hab. In tuberibus putridis Solani tuberosi una cum F. lutulato var. zonato, Ithaca, New York, Amer. bor.

Measurements of conidia on different media are as follows:

On red raspberry cane plug, culture twenty-three days old:

(1) Conidia from pseudopionnotes

Conidia: 1–septate, 7 per cent, 15 x 2.3 (10–23 x 2.2–2.5)μ
2–septate, 2.5 per cent
3–septate, 17 per cent, 32 x 3.4 (22–43 x 2.8–4.1)μ
4–septate, 7 per cent, 40 x 3.8 (35–45 x 3–4.3)μ
5–septate, 63.5 per cent, 47 x 4.2 (38–51 x 3.9–4.3)μ
6–septate, 3 per cent, 52–60 x 4.1–4.4μ (only a few measured)
7–septate, very few, 52–60 x 4.1–4.4μ (only a few measured, the thickest, swollen, 6.2μ in diameter)

(2) Chlamydospores

(a) Unicellular, in conidia, 6–12.5 x 6–8μ
(b) Unicellular, in mycelium, 8–17 x 7–14μ

On slightly acidified hard potato agar, culture nineteen days old; conidia from pseudopionnotes:

Conidia: 1–septate, 1 per cent
2–septate, 2 per cent
3–septate, 57 per cent, 37.5 x 3.6 (32–50 x 3–4)μ
4–septate, 17 per cent, 44 x 3.7 (38–60 x 3.5–4.4)μ
5–septate, 20 per cent, 45 x 4.1 (40–60 x 3.8–4.4)μ
$\left.\begin{array}{l}\text{6–septate}\\\text{7–septate}\end{array}\right\}$ 3 per cent

On potato tuber plug, culture seventy-six days old; conidia from aërial mycelium:

Conidia: 0–septate, 5 per cent
1–septate, 15 per cent
2–septate, 10 per cent
3–septate, 55 per cent, 24 x 3.5 (17–35 x 3–4)μ
4–septate, 7 per cent
5–septate, 8 per cent, 40 x 4.1 (35–43 x 3.5–4.4)μ

On hard lima-bean agar with 2 per cent glucose, culture eight days old; conidia from pseudopionnotes:

Conidia: 3–septate, 3 per cent, 41 x 3.8 (35–44 x 3.5–4.1)μ
4–septate, 5 per cent
5–septate, 90 per cent, 47 x 4.2 (43–51 x 3.9–4.7)μ
6–septate, 2 per cent

On hard lima-bean agar, culture sixteen days old, most of the conidia swollen (only normal, not swollen, conidia, were measured):

Conidia: 1–septate, 9 per cent, 14.7 x 2.5 (12–19.5 x 2.3–3)μ
2–septate, very rare
3–septate, 37 per cent, 33 x 3.5 (18–41 x 3–4.1)μ
4–septate, 14 per cent
5–septate, 29 per cent, 47 x 3.9 (38–56 x 3.5–4.4)μ
6–septate, 7 per cent, 50 x 4 (43–58 x 3.9–4.4)μ
7–septate, 4 per cent, 50 x 4.1 (49–56 x 4–4.3)μ
8–septate, exceptional, 61 x 4.4μ (only one found and measured)

Average of the above measurements:

Conidia: 0–septate, 1 per cent
1–septate, 6 per cent
2–septate, 3 per cent
3–septate, 34 per cent, 33.5 x 3.6μ
4–septate, 10 per cent
5–septate, 42 per cent, 45.2 x 4.1μ
6– and 7–septate, 4 per cent, 50 x 4.05μ
8–septate, very rare, 61 x 4.4μ (only one measured)

30. *Fusarium sanguineum* var. **pallidium** n. var. (Figs. 1K and 26; Pl. III, figs. 5 and 6; Pl. VII, fig. 7)

Differs from *F. sanguineum* by better development of mycelium, by much slower rate of colony growth, by paler color of substratum and conidia (Pl. III, figs. 5 and 6), and by chlamydospores which are intercalary, as in *F. sanguineum*, but mostly in conidia and not in mycelium, and of much rarer occurrence than in *F. sanguineum*.

Hab. On rotted tubers of *Solanum tuberosum*, in association with *F. oxysporum*, South Dakota.

Measurements of conidia on different media are as follows:

On slightly acidified hard potato agar, culture three days old; conidia from pseudopionnotes:

Conidia: 2–septate, rare
3–septate, 53 per cent, 45 x 3.9 (38–56 x 3.5–4.1)μ
4–septate, 20 per cent, 40 x 4 (40–57 x 3.9–4.1)μ
5–septate, 20 per cent, 53 x 4.1 (47–60 x 3.9–4.3)μ
6– and 7–septate, 7 per cent, 55 x 4.3 (52–61 x 4.1–4.8)μ

On red raspberry cane plug, culture thirty-two days old; conidia from aërial mycelium:

Conidia: 1–septate, few
3–septate, 43 per cent, 30 x 3.8 (19–42 x 2.6–4.3)μ
4–septate, 36 per cent, 36 x 4 (31–42 x 3.5–4.3)μ
5–septate, 21 per cent, 39 x 4.1 (33–43 x 3.9–4.7)μ

On hard lima-bean agar with 2 per cent glucose, culture eight days old; conidia from pseudopionnotes:

Conidia: 3–septate, 60 per cent, 41 x 3.7 (35–48 x 3.5–4.1)μ
4–septate, 25 per cent, 51 x 3.8 (44–60 x 3.5–4.1)μ
5–septate, 15 per cent, 55 x 3.8 (52–56 x 3.5–4)μ

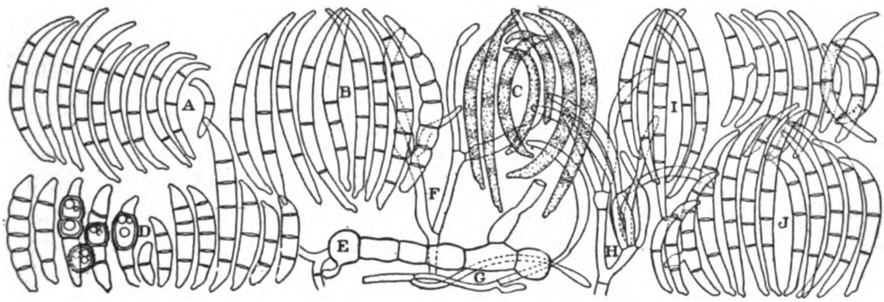

FIG. 26.—*Fusarium sanguineum var. pallidium.* A, *Pseudopionnotal conidia from 32-days-old culture on red raspberry cane plug;* B, *pseudopionnotal conidia from 3-days-old culture on slightly acidified hard potato agar;* C, *pseudopionnotal conidia with densely granulated content and indistinct septation from 8-days-old culture on hard lima-bean agar with 2 per cent glucose;* D, *conidia (normal, swollen, and with chlamydospores) from aërial mycelium from 35-days-old culture on whole steamed potato tubers;* E, *chlamydospore-like swellings in mycelium from 176-days-old culture on corn agar;* F, G, H, *conidiophores from 14-days-old culture on hard lima-bean agar;* I, *pseudopionnotal conidia from 35-days-old culture on whole steamed potato tubers;* J, *pseudopionnotal and aërial conidia from 14-days-old culture on hard lima-bean agar*

On whole steamed potato tuber, culture thirty-eight days old:

(1) From a tuft of conidiophores over dry surface of the tuber;[44] type of spores very much like that of *F. discolor* var. *triseptatum*

Conidia: 1–septate, 2 per cent
2–septate, 7 per cent, about 17 x 3.6μ
3–septate, 72 per cent, 24 x 4.5 (19–32 x 4–4.8)μ

[44] This type is very different from the general type, and therefore was not taken into account for average size of conidia.

4–septate, 15 per cent, 26 x 4.7 (24–30 x 4.6–5.2)μ
5–septate, 4 per cent, 28 x 4.7 (26–32 x 4.2–5.2)μ, the largest 45.5 x 5.2μ

(2) From pionnotes over the cut surface of the tuber; spore type close to that of *F. arcuosporum*

Conidia: 3–septate, 68 per cent, 41 x 3.2 (29–48 x 2.9–3.5)μ
4–septate, 20 per cent, 44 x 3.4 (36–51 x 3.2–4)μ
5–septate, 12 per cent, 48 x 3.4 (40–57 x 3–3.7)μ

On hard lima-bean agar, culture fourteen days old; conidia from pseudopionnotes:

Conidia: 1–septate, 2 per cent, 21 x 2.8μ (only three measured)
2–septate, exceptional
3–septate, 83 per cent, 37 x 3.5 (33–42 [61 exceptional] x 3–3.9)μ
4–septate, 12 per cent
5–septate, 3 per cent, 47 x 3.8 (42–60 x 3.5–4)μ

On the same medium and of the same age as the above, but from a semi-dry minute sporodochium near the upper margin of the slant:

Conidia: 1–septate, 1 per cent
3–septate, 56 per cent, 43 x 3.8 (37–48 x 3.5–4.1)μ
4–septate, 29 per cent
5–septate, 14 per cent, 44 x 3.9 (40–49 x 3.5–4.2)μ

31. **Fusarium bullatum** n. sp. (Figs. 1A₁ and 27)

Conidia typically somewhat less arcuate than the other species of the same section, less pointed toward the apex, and broader, usually distinctly pedicellate, mostly 5–septate, 42 x 4.3 (31–47 x 4.1–4.9)μ, from pale cream to salmon in color; chlamydospores intercalary in mycelium, mostly in chains and from small to large clusters; aërial mycelium nearly always well developed, of uniform medium height and density, nearly pure white in color; substratum on various agars from colorless to a tint of light buff.

Hab. On rotted tuber of *Solanum tuberosum*, together with *F. bullatum* var. *roseum* and with *F. oxysporum* var. *resupinatum*, in Iowa.

Latin description.—Conidiis typice paulo minus arcuatis quam ceteris ejusdem sectionis speciebus, minus in apicem acutis, latioribus, plerumque distincte pedicellatis, plerumque 5-septatis, 42 x 4.3 (31–47 x 4.1–4.9)μ, e pallide "cream color" (R) "salmon color" (R); chlamydosporis intercalaribus in mycelio, plerumque catenulatis, parvis vel magnis uveosis; aerio mycelio semper plene maturo, uniformi mediocri altitudine atque densitate, ferme pure albo; substrato in agaribus variis ex hyalino pallide luteolo tincto.

Hab. In tuberibus putridis Solani tuberosi una cum F. bullato var. roseo et cum F. oxysporo var. resupinato, Iowa, Amer. bor.

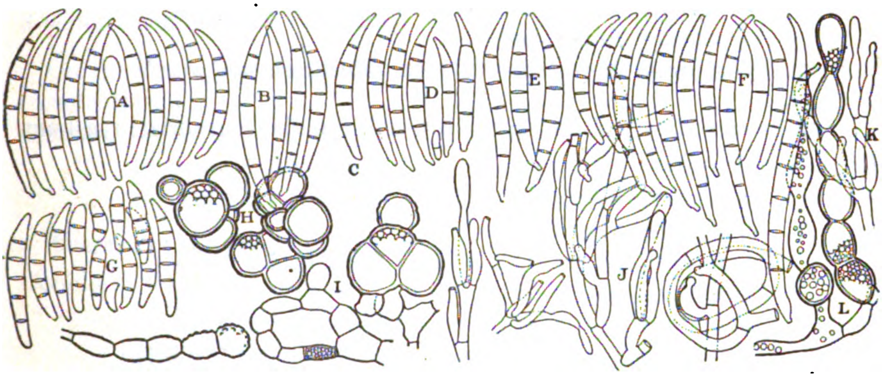

FIG. 27.—*Fusarium bullatum.* A, *Pseudopionnotal conidia from 10-days-old culture on hard lima-bean agar;* B, *pseudopionnotal conidia from 77-days-old culture on red raspberry cane plug;* C, *a typical conidium from 51-days-old culture on potato tuber plug;* D, *conidia from 76-days-old culture on potato tuber plug;* E, *conidia from 19-days-old culture on hard lima-bean agar;* F, *pseudopionnotal conidia from 7-days-old culture on hard potato agar;* G, *conidia,* H, *chlamydospores, from 42-days-old culture on rye straw;* I, *chlamydospores from 77-days-old culture on red raspberry cane plug;* J, *conidiophores from 7-days-old culture on hard potato agar;* K, *conidiophore from 10-days-old culture on hard lima-bean agar;* L, *chains of chlamydospores from 175-days-old culture on corn agar*

Measurements of conidia on different media are as follows:

On slightly acidified hard potato agar, culture seven days old; conidia from pseudopionnotes:

Conidia: 3-septate, 16 per cent, 36 x 3.8 (29–50 x 3.5–4.9)μ
4-septate, 19 per cent, 43 x 4.1 (33–50 x 3.9–4.9)μ
5-septate, 65 per cent, 45 x 4.4 (37–63 x 4.1–4.9)μ
6- to 8-septate, rare, 65 x 4.9 (60–82 x 4.7–5.3)μ

On red raspberry cane plug, culture seventy-seven days old; conidia from aërial mycelium close to substratum:

Conidia: 3–septate, 25 per cent
4–septate, 20 per cent
5–septate, 55 per cent, 48 x 4.1 (42–53 x 3.5–4.4)μ

On potato tuber plug, culture seventy-six days old; conidia from aërial mycelium:

Conidia: 1–septate, 5 per cent
2–septate, 10 per cent
3–septate, 45 per cent, 31 x 3.7 (22–39 x 3.5–4.6)μ
4–septate, 20 per cent
5–septate, 20 per cent, 39 x 4.2 (35–45 x 4–4.4)μ

Same as preceding, culture eighty days old; conidia from aërial mycelium:

Conidia: 0–septate, 1 per cent
1–septate, 4 per cent
2–septate, 1 per cent
3–septate, 40 per cent, 30 x 3.7 (22–39 x 3.1–4.1)μ
4–septate, 20 per cent
5–septate, 34 per cent, 41 x 4.2 (35–49 x 3.5–4.7)μ
6– to 9–septate, rare (the largest, 9–septate, 56 x 5.7μ)

On hard lima-bean agar with 2 per cent glucose, culture nineteen days old; conidia from pseudopionnotes:

Conidia: 3–septate, 2 per cent, 35 x 3.8μ (only three measured)
4–septate, 1 per cent, 38 x 3.9μ (only four measured)
5–septate, 97 per cent, 47 x 4.4 (43–54 x 4–4.7)μ
6–septate, rare, 51 x 4.5μ (only three measured, 48–53 x 4.3–4.8μ)

On potato stem plug, culture one hundred and fourteen days old; conidia from aërial mycelium:

Conidia: 3–septate, 16 per cent
4–septate, 14 per cent
5–septate, 70 per cent, 41 x 4.35 (36–46 x 4–4.7)μ

On hard lima-bean agar, culture ten days old; conidia from pseudopionnotes:

Conidia: 0–septate, rare
1–septate, 5 per cent
2–septate, rare
3–septate, 15 per cent
4–septate, 10 per cent
5–septate, 70 per cent, 43 x 4.1 (35–50 x 3.8–4.7) μ

In some cases 5–septate conidia were up to 100 per cent, in others conidia of lower septation were as high as 50 per cent. Of the smaller, 3–septate conidia were dominant.

On rye straw, culture fifty days old; conidia from aërial mycelium close to substratum:

Conidia: 3–septate, 10 per cent
4–septate, 5 per cent
5–septate, 85 per cent, 31.25 x 4.1 (27–36 x 3.9–4.6) μ

Average of the above measurements:

Conidia: 0–septate, rare
1–septate, 2 per cent
2–septate, 1.5 per cent
3–septate, 21 per cent, 33 x 3.75 μ
4–septate, 15 per cent
5–septate, 60.5 per cent, 42 x 4.3 μ
6– to 8–septate, very rare, 58 x 4.7 μ

32. *Fusarium bullatum* var. **roseum** n. var. (Fig. 28; Pl. III, fig. 2)

Differs from *F. bullatum* mainly by its red substratum (on agar rich in glucose, see Plate III, figure 2) and by higher septation of conidia.

Hab. Same as that of *F. bullatum.*

This organism and *F. bullatum* are in general, especially in minute details of the character of the mycelium and in the chlamydospores, very much alike, and both were isolated from the same planting of diseased tissue of a rotted potato tuber and separated out on the first dilution. It is possible that they represent an example of a sudden and permanent variation of one Fusarium in pure culture.

IX. SECTION ELEGANS Wr., Phytopath. 3:28, fig. 1, E, F, S, T, U, V. 1913

Fusaria with ellipsoidal, 0- and 1-septate, microconidia; macroconidia typically 3-septate, often also 4- or 5-septate, more or less gradually pointed toward apex, pedicellate; chlamydospores intercalary and terminal in and on mycelial hyphæ, always present, and often also in and on conidia: color of conidia mostly pinkish buff; color of substratum, and of aërial mycelium when present (on potato agar rich in glucose and on rice), typically of various vinaceous hues, from light pinkish to dense purple.

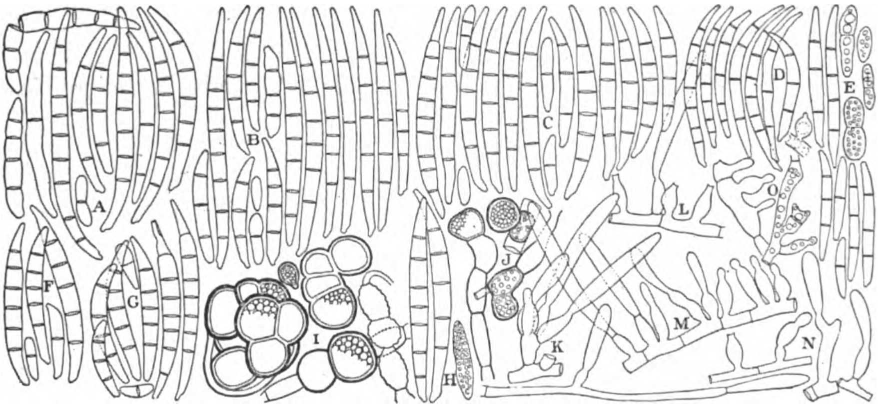

FIG. 28.—*Fusarium bullatum var. roseum.* A, *Pseudopionnotal conidia from 7-days-old culture on slightly acidified hard potato agar;* B, *pseudopionnotal conidia from 9-days-old culture on hard lima-bean agar;* C, *pseudopionnotal conidia from 12-days-old culture on hard lima-bean agar;* D, *sporodochial conidia from 71-days-old culture on potato stem plug;* E, *pseudopionnotal conidia (many are swollen and with oil drops) from 35-days-old culture on corn meal;* F, *conidia from 37-days-old culture on hard oat gar;* G, *conidia from 67-days-old culture on red raspberry cane plug;* H, *pseudopionnotal conidia from 16-days-old culture on hard lima-bean agar (the two at the left typical for older growth, the one at the right for young growth);* I, *chlamydospores, intercalary in chains and in clusters, from 67-days-old culture on red raspberry cane plug;* J, *chlamydospores from 12-days-old culture on hard lima-bean agar;* K, L, M, *conidiophores from 7-days old culture on slightly acidified hard potato agar;* N, *conidiophores from 12-days-old culture on hard lima-bean agar;* O, *conidiophores from 35-days-old culture on corn meal*

33. *Fusarium orthoceras* Ap. et Wr. (Figs. 1, I_1 to K_1, and 29)

Appel, O., and Wollenweber, H. W. Arb. K. biol. Anst. Land- u. Fo stw. 8:141–156; Pl. I, figs. 60 to 64; Pl. III, fig. 2. 1910. Wollenweber, H. W., Phytopath. 3:30, fig. 1s. 1913.

Microconidia always greatly in excess; macroconidia ranging from rare to several per cent of the total number of conidia, mostly nearly straight, sometimes slightly curved, typically 3-septate, 36 x 3.85 (25–40 x 3.2–4)μ; aërial mycelium usually well developed, from white to a tint of olive-buff; substratum, on potato agar rich in glucose, colorless at first, then from russet vinaceous to deep brownish vinaceous; no sporodochia; no pseudopionnotes; no sclerotia. Not the same as *F. oxysporum*.

Hab. Roots and tubers of Solanaceæ, also on various other hosts and in soil, in Europe and North America.

The organism was not isolated by the writer. The original culture was obtained from the Centralbureau der Association Internationale des Botanistes, Amsterdam, Holland, and was studied in conjunction with the other Fusaria. The above description is in the main the same as that given by Wollenweber.

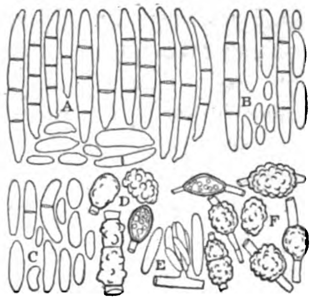

FIG. 29.—*Fusarium orthoceras.* A, *Conidia from 18-days-old culture on slightly acidified hard potato agar;* B, *conidia from 26-days-old culture on potato tuber plug;* C, *conidia from 15-days-old culture on hard lima-bean agar with 2 per cent glucose;* D, *chlamydospores from 18-days-old culture on slightly acidified hard potato agar;* E, *conidia, some in a ball, with conidiophore of common type, from 30-days-old culture on corn agar;* F, *chlamydospores from 53-days-old culture on potato tuber plug*

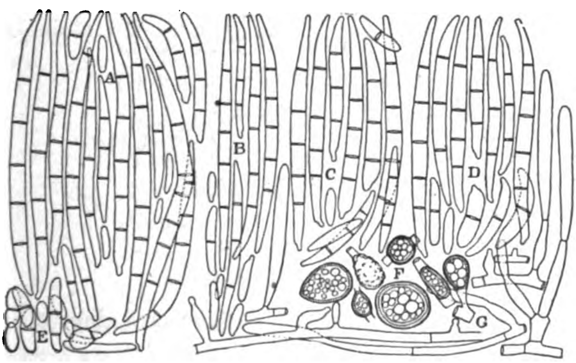

FIG. 30.—*Fusarium angustum.* A, *Pseudopionnotal conidia from 4-days-old culture on slightly acidified hard potato agar;* B, *conidiophores from surface of the exposed substratum from 25-days-old culture on corn agar;* C, *pseudopionnotal conidia from 9-days-old culture on hard lima-bean agar with 2 per cent glucose;* D, *pseudopionnotal conidia from 8-days-old culture on hard lima-bean agar;* E, *microconida from aërial mycelium;* F, *chlamydospores from 74-days-old red raspberry cane plug;* G, *conidiophores from 9-days-old culture on hard lima-bean agar with 2 per cent glucose*

34. **Fusarium angustum** n. sp. (Figs. 1, G_1 and H_1, and 30)

Conidia gradually pointed toward apex, from slightly curved to nearly straight or an-

guiform, usually distinctly pedicellate, mostly 3–septate, 45.64 x 3.52 (42–49 x 3.3–3.6)μ, often 0– to 5–septate, sometimes 6– to 8–septate; on various agars usually producing thin pseudopionnotes, otherwise very similar to *F. oxysporum.*

Hab. In discolored fibrovascular bundles of tubers of *Solanum tuberosum*, Ithaca, New York.

Latin description.—Conidiis gradatim in apicem acutis, paulum curvatis vel prope rectis anguiformibusque, plerumque distincte pedicellatis, plerumque 3–septatis, 45.64 x 3.52 (42–49 x 3.3–3.6)μ, saepe 0–5–septatis, interdum 6–8–septatis; in variis agaribus tenues pseudopionnotes plerumque exhibentibus, aliter simillimis F. oxysporo.

Hab. In tuberum fasciculis decoloratis fibro-vascularibusque Solani tuberosi, Ithaca, New York, Amer. bor.

Measurements of conidia on different media are as follows:

On slightly acidified hard potato agar, culture four days old; conidia from pseudopionnotes:

Conidia: 0–septate, 6 per cent, 12 x 2.5 (8–18 x 1.8–3.5)μ
1–septate, 7 per cent, 32 x 2.9 (19–52 x 2.5–4.2)μ
2–septate, 2 per cent, 32 x 2.7 (30–39 x 2.5–3)μ
3–septate, 44 per cent, 42.2 x 3.3 (31–69 x 2.5–4.4)μ
4–septate, 13 per cent, 60.4 x 3.8 (47–70 x 3.5–4.4)μ
5–septate, 27 per cent, 63 x 3.9 (43–81 x 3.5–4.1)μ
6– to 8–septate, 1 per cent, 90 x 4.1 (80–102 x 4–4.4)μ

On red raspberry cane plug, culture seventy-four days old:

Conidia: 0–septate, 90 per cent
1–septate, 7 per cent
3–septate, 3 per cent, 39.4 x 3.81 (30–50 x 3–4.8)μ

On hard lima-bean agar with 2 per cent glucose, culture nine days old; conidia from pseudopionnotes:

Conidia: 0–septate, 54 per cent, 10 x 2.8 (5–15 x 2.7–3.1)μ
1–septate, 7 per cent, 18 x 2.9 (15–22 x 2.7–3.1)μ
2–septate, 3 per cent
3–septate, 20 per cent, 43 x 3.6 (29–53 x 3–4.1)μ
4–septate, 8 per cent
5–septate, 8 per cent, 59 x 4.5 (52–70 x 3.9–4.8)μ
6–septate, few, 70 x 4.7μ (only one measured)

On hard lima-bean agar, culture eight days old; conidia from pseudopionnotes (measurements made in April):

Conidia: 0–septate, 39 per cent, 11 x 2.6 (8.7–14 x 2.1–3.2)μ
1–septate, 17 per cent, 18 x 3.2 (14–23 x 2.9–3.9)μ
2–septate, 3 per cent, 24 x 3.3μ (only four measured)
3–septate, 32 per cent, 49 x 3.6 (42–55 x 3.5–4.8)μ
4–septate, 2 per cent, 53 x 4μ (only four measured)
5–septate, 6 per cent, 58 x 4.3 (52–65 x 3.5–4.8)μ
6–septate, 1 per cent, 73 x 4.7μ (only one measured)

On same media, culture nine days old (measurements made in May):

Conidia: 0–septate, 11 per cent, 10 x 2.5 (5–15 x 1.6–3.3)μ
1–septate, 9 per cent, 17 x 3.1 (12–24 x 2.6–4)μ
2–septate, 1 per cent
3–septate, 43 per cent, 49 x 3.6 (31-54 x 2.7–4.1)μ
4–septate, 13 per cent
5–septate, 23 per cent, 50 x 4 (54–71 x 3.5–4.7)μ

Average of the above measurements:

Conidia: 0–septate, 27.5 per cent, 11 x 2.6μ
1–septate, 10 per cent, 21 x 3μ
2–septate, 2 per cent, 28 x 3μ
3–septate, 35 per cent, 45.64 x 3.52μ
4–septate, 9 per cent, 56.7 x 3.9μ
5–septate, 16 per cent, 60 x 4.2μ
6–septate, 0.5 per cent, 78 x 4.5μ
8–septate, very rare, 78 x 4.5μ

35. *Fusarium redolens* Wr.[45] var. Solani n. var. (Figs. 1P₁ and 31; Pl. II, figs. 3 and 4; Pl. V, fig. 2)

Macroconidia typically more or less gradually attenuate, sometimes suddenly constricted at the apex, pedicellate, typically broader toward and

[45] *Fusarium redolens* Wr. is described by its author (see Wollenweber, Phytopath. 3: 29–30, fig. 1 m, 1913) as follows: "Differs from all the above-mentioned species [*F. oxysporum*, *F. tracheiphilum*, *F. vasinfectum*, *F. vasinfectum* var. *inodoratum*, *F. lycopersici*, and *F. niveum*] in the large size of its triseptate conidia, 30–40 x 4.5–5.5μ, and in the color of the brownish white conidial masses. A lilac odor is produced on rice and milk. No blue sclerotia. Vascular parasite, cause of wilt and foot disease of *Pisum sativum*. Distribution unknown."

more curved near apex, 3–septate, 36.4 x 4.86 (31–41 x 4.3–5)μ, often also 4– and 5–septate, usually in numerous from small to medium (up to $2\frac{1}{2}$ millimeters, commonly $\frac{1}{2}$ millimeter, in diameter) sporodochia, sometimes, especially on different agars and in an early stage of culture growth, in pseudopionnotes; from nearly white in color when in small powdery masses, to a bright orange color when in comparatively large sporodochia on nearly dry potato stems; mostly, however, from a light pinkish cinnamon to a pinkish buff; aërial mycelium sometimes medium well developed but usually very scant, short, from white to somewhat grayish or brownish gray in color (Pl. II, fig. 3); color of substratum, on agar rich in glucose, as shown on Plate II, figure 4, which is different from all the other Fusaria of the section Elegans.

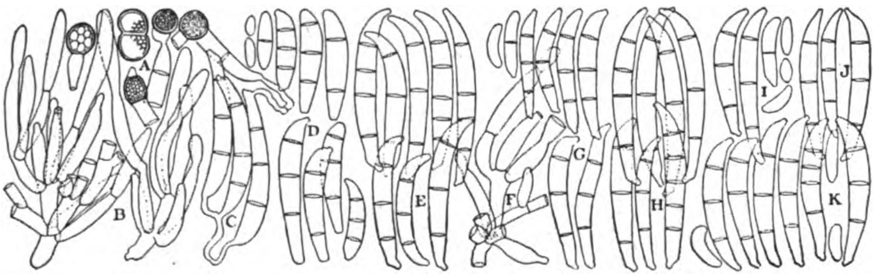

FIG. 31.—*Fusarium redolens var. Solani.* A, *Chlamydospores produced by conidia and mycelium from 120-days-old culture on potato stem plug;* B, *conidiophores from 14-days-old culture on slightly acidified hard potato agar;* C, *anastomosed conidia from 13-days-old culture on hard lima-bean agar;* D, *sporodochial conidia from 35-days-old culture on potato stem plug;* E, *pseudopionnotal conidia,* F, *conidiophores, from 14-days-old culture on slightly acidified hard potato agar;* G, *sporodochial conidia from 63-days-old culture on whole grain of rye;* H, *normal pseudopionnotal conidia from 13-days-old culture on hard lima-bean agar;* I, *pseudopionnotal conidia from 9-days-old culture on hard lima-bean agar with 2 per cent glucose (the longest spore is typical);* J, *pseudopionnotal conidia from 120-days-old culture on potato stem plug;* K, *sporodochial conidia from 48-days-old culture on red raspberry cane plug*

Hab. On rotted tubers of *Solanum tuberosum*, Atlanta, New York.

Differs from *F. redolens* Wr. by somewhat narrower conidia and by color of substratum,[46] especially on potato agar rich in glucose.

Measurements of spores on different media are as follows:

[46] Wollenweber does not directly give color of substratum of his *F. redolens*, but judging from his definite negative statement in regard to *F. conglutinans* Wr. it appears evident that *F. redolens* does not differ noticeably in color from *F. oxysporum* and the majority of other species of the section Elegans.

On slightly acidified hard potato agar, culture fourteen days old; conidia from pseudopionnotes:

Conidia: 2–septate, 0.5 per cent, 26 x 4.7μ
3–septate, 93.5 per cent, 36 x 5 (26–49 x 4.3–5.8)μ
4–septate, 6 per cent, 41.6 x 5.3 (38–46 x 4.9–6.1)μ
5– and 6–septate, rare, 43–53 x 5–6μ

On red raspberry cane plug, culture forty-eight days old; conidia from a small sporodochium:

Conidia: 0–septate, 2 per cent
1–septate, 1 per cent
3–septate, 97 per cent, 35.6 x 5 (28–45 x 4–5.9)μ

On hard lima-bean agar, culture nine days old; conidia from pseudopionnotes:

Conidia: 0–septate, 17 per cent, 10 x 3.6 (6–16 x 3–4.3)μ
1–septate, 10 per cent, 20 x 3.9 (14–28 x 3.5–4.7)μ
2–septate, 3 per cent
3–septate, 70 per cent, 34 x 4.9 (28–43 x 4.3–5.3)μ
4–septate, rare

On potato tuber plug, culture ninety-nine days old; conidia from a medium small sporodochium:

Conidia: 2–septate, rare, 27 x 4.8μ
3–septate, 100 per cent, 33.6 x 4.9 (29–39 x 4.6–5.7)μ

On potato stem plug, culture one hundred and thirteen days old:

(1) Chlamydospores, mostly unicellular

Chlamydospores: 0–septate, 6.5 x 6.1 (4.7–11 x 5.2–7.5)μ

(2) Conidia from a sporodochium

Conidia: 0– and 1–septate, very rare
3–septate, 100 per cent, 34.5 x 4.5 (24–39 x 3.9–5.1)μ
4–septate, very rare, about the same size as 3–septate

On whole steamed potato tuber, culture forty-nine days old; conidia from a medium small sporodochium:

Conidia: 0– and 1–septate, rare
3–septate, 100 per cent, 31 x 4.3 (29–36 x 4.1–4.8)μ

On rye grain, culture sixty-three days old; conidia from a small sporodochium:

(1) Conidia: 0–septate, 5 per cent
1–septate, 3 per cent
2–septate, 1 per cent
3–septate, 91 per cent, 34.6 x 4.6 (28–41 x 3.8–5.2)μ
4–septate, rare
5–septate, very rare

(2) Chlamydospores in mycelium, terminal, about the same size as those on potato stem plug

On corn agar, culture one hundred and seventy-three days old, chlamydospores intercalary and terminal:

Chlamydospores: 0–septate (in conidia), 9.4 x 8.3 (7–11 x 5.2–9)μ
1–septate (in mycelium), 15 x 9 (11–20 x 7–11)μ

On hard lima-bean agar with 2 per cent glucose, culture one hundred and eighteen days old:

(1) Chlamydospores not numerous; in conidia, 0–septate, 8.7 x 8.5μ; in mycelium, 0– and 1–septate, and also in small clusters of three

(2) Sporodochial conidia

Conidia: 1–septate, rare
3–septate, 94 per cent, 37 x 5 (28–44 x 4.6–5.9)μ
4–septate, 6 per cent, 40 x 5.05 (37–44 x 4.7–5.9)μ
5–septate, rare, about the same size as 4–septate

On hard lima-bean agar, culture five days old; chlamydospores (in conidia) not observed; conidia from pseudopionnotes:

Conidia: 0–septate, 10 per cent, 11 x 3.6μ
1–septate, 3 per cent, 22 x 4μ
2–septate, 1 per cent
3–septate, 86 per cent, 41 x 4.9 (33–53 x 4.6–5.2)μ
4–septate, rare
5–septate, very rare

On the same medium as above, culture thirteen days old; conidia from pseudopionnotes:

Conidia: 0–septate, rare
3–septate, 97 per cent, 41 x 4.9 (34–49 x 4.2–5.2)μ
4–septate, 3 per cent, 43 x 5 (36–48 x 4.7–5.2)μ
5–septate, rare, 45 x 5.1 (43–47 x 4.8–5.2)μ

Average of the above measurements:

Conidia: 0–septate, 3.5 per cent, 10.5 x 3.6μ
1–septate, 1.5 per cent, 21 x 3.95μ
2–septate, 0.5 per cent, 26.5 x 4.75μ
3–septate, 93 per cent, 36.4 x 4.86μ
4–septate, 1.5 per cent, 41.5 x 5.12μ
5–septate, rare, 44.3 x 5.2μ
6–septate, very rare

36. **Fusarium lutulatum** n. sp. (Figs. 1F_1 and 32; Pl. II, figs. 5 and 6; Pl. V, fig. 3)

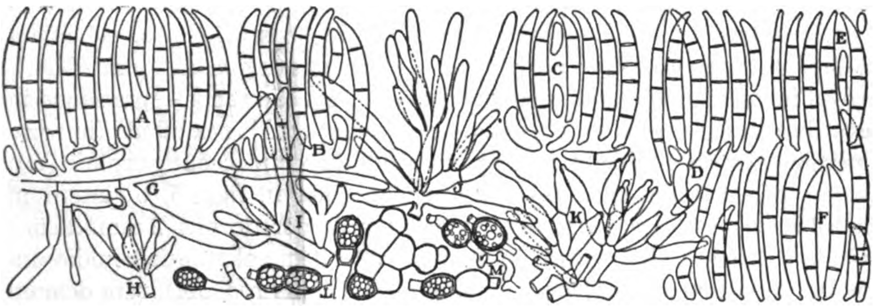

FIG. 32.—*Fusarium lutulatum.* A, *Conidia from plectenchymic sporodochium from 60-days-old culture on red raspberry cane plug;* B, *pseudopionnotal conidia from 9-days-old culture on hard lima-bean agar with 2 per cent glucose;* C, *pseudopionnotal conidia from 5-days-old culture on hard lima-bean agar;* D, *sporodochial conidia from 63-days-old culture on whole grain of rye;* E, *sporodochial conidia from 49-days-old culture on whole steamed potato tuber;* F, *pseudopionnotal conidia from 23-days-old culture on slightly acidified hard potato agar;* G, H, I, J, *conidiophores from 5-days-old culture on hard lima-bean agar;* K, *conidiophores from 23-days-old culture on slightly acidified hard potato agar;* L, *terminal and intercalary chlamydospores from 63-days-old culture on whole grain of rye;* M, *chlamydospores from 25-days-old culture on corn agar*

Macroconidia gradually attenuate toward the apex, usually distinctly pedicellate and uniformly curved throughout, without stronger curvature near apex, typically 3–septate, 34 x 4 (28–38 x 3.7–4.5)μ, also 2– to 5–septate; from small to medium sporodochia (up to 2 millimeters in diameter), often converging into pseudopionnotes; aërial mycelium, when present, short, (mostly from 1 to 2 millimeters high), white, often, especially on agars in plate cultures, absent; color of conidia from nearly white

(on aërial mycelium in the form of coarse powder) to dark vinaceous purple; typical variation of spore color shown in Plate II, figures 5 and 6; sometimes on potato stem plug, from one to a few large sporodochia (2 millimeters in diameter) of a bright orange color produced; substratum from colorless to that of the conidial masses; small bluish black sclerotia (½ millimeter in diameter) sometimes produced, and then in great numbers all over the substratum (on potato tuber plug); zonation of colony very faint or none on neutral agars in plate cultures.

Hab. On soft and dry rotted tubers of *Solanum tuberosum*, Atlanta, New York.

Latin description.—Macroconidiis gradatim in apicem attenuatis, plerumque distincte pedicellatis et aequabiliter curvatis, non ad apicem curvatioribus, typice 3-septatis, 34 x 4.23 (28–38 x 3.7–4.5)μ, vel etiam 2–5-septatis; sporodochiis minutis vel mediocribus (usque ad 2 mm. diam.), saepe in pseudopionnotes vergentibus; aerio mycelio saepe — praecique in agaribus in culturis in patellis factis — absente; conidiis ex albido (in aerio mycelio similibus magnis granis pulveris) "dark vinaceous purple" (R); vide typicam spororum coloris variationem, Tab. II, figg. 5, 6; interdum in tuberibus Solani tuberosi, vel unis vel paucis sporodochiis (2 mm. diam.) nitide "orange" (R); substrato hyalino vel eodem colore quo conidiorum moles; interdum sclerotiis minutis livido-atris (½ mm. diam.), tum demum eorundem magnis numeris passim in substrato in tuberibus Solani tuberosi; zonatione coloniae vel maxime indistincta vel nulla in agaribus neutralibus in culturis in patellis factis.

Hab. In mollibus vel aridis putridis tuberibus Solani tuberosi, Atlanta, New York, Amer. bor.

Measurements of spores on different media are as follows:

On slightly acidified hard potato agar, culture twenty-three days old; conidia from pseudopionnotes:

Conidia: 0-septate, 4.5 per cent, 9 x 2.7 (6–14 x 2.5–3)μ
1-septate, 1 per cent, 18 x 3.2 (13–22 x 2.6–4)μ
2-septate, 0.5 per cent, 19.5 x 3.2 (17–23 x 2.7–3.5)μ
3-septate, 89 per cent, 35.2 x 4.5 (23–38 x 3.5–4.7)μ
4-septate, 4.8 per cent, 37.8 x 4.6 (31–40 x 4.3–4.7)μ
5-septate, 0.2 per cent, 45 x 4.7 (38–50 x 4.7)μ

On red raspberry cane plug, culture sixty days old; conidia from a medium-sized sporodochium:

Conidia: 0–septate, 25 per cent
1–septate, 5 per cent
2–septate, 1 per cent
3–septate, 65 per cent, 38 x 4.2 (27–44 x 3.5–4.7)μ
4–septate, 4 per cent, 42 x 4.4 (36–49 x 3.7–4.7)μ
5–septate, rare, about the size of 4–septate conidia

On hard lima-bean agar, culture nine days old; conidia from aërial mycelium:

Conidia: 0–septate, 57 per cent, 8.5 x 2.8 (7–12 x 2.6–3.5)μ
1–septate, 16 per cent, 14.5 x 3.25 (11–21 x 2.9–3.8)μ
2–septate, 3.5 per cent
3–septate, 23 per cent, 28 x 3.9 (23–37 x 3.5–4.4)μ
4–septate, 0.5 per cent, 35 x 3.9 (30–37 x 3.5–4.4)μ

On same media, culture twenty-two days old; conidia from small sporodochia:

Conidia: 0–septate, 3 per cent
1–septate, 1 per cent
2–septate, rare
3–septate, 84 per cent, 36 x 4 (29–40 x 3.9–4.4)μ
4–septate, 10 per cent, 39 x 4.3 (33–42 x 3.9–4.7)μ
5–septate, 2 per cent, 41 x 4.2μ (only a few measured)

On hard potato agar, culture thirty-one days old:

(1) Conidia from pseudopionnotes

Conidia: 0–septate, 26 per cent, 7.4 x 2.7 (5.2–12 x 2.6–3.5)μ
1–septate, 4 per cent, 13 x 3.3μ (only three measured)
2–septate, rare, 20 x 3.7μ (only three measured)
3–septate, 54 per cent, 35 x 4.2 (20–41 x 3.4–4.8)μ
4–septate, 12 per cent, 40 x 4.4 (35–44 x 4–4.8)μ
5–septate, 4 per cent, 43 x 4.8 (41–46 x 4–4.8)μ

(2) Chlamydospores (abundant)
(a) Terminal, 0–septate, on mycelium, 8 x 6.6 (7–9 x 6–7)μ
(b) Intercalary, in mycelium
0–septate, 8.2 x 6.2 (6–9 x 4.5–8)μ
1–septate, 11 x 5.7μ (only a few measured)
(c) In conidia, 0–septate, 6.5 x 5.9μ

On potato tuber plug, culture ninety-nine days old:
(1) Conidia from a sporodochium

Conidia: 0–septate, 5 per cent, 6.2 x 2.4 (4.5–8 x 2–2.9)μ
1–septate, 1 per cent, 13 x 2.7μ (only a few measured)
2–septate, rare, 20 x 3.3μ (only a few measured)
3–septate, 92 per cent, 32 x 3.8 (20–38 x 3–4.2)μ
4–septate, rare, 37 x 4.1μ (only one measured)
5–septate, very rare, about the size of 4–septate

(2) Chlamydospores, numerous, mostly in conidia
0–septate, 6.8 x 5.1 (5.2–7.2 x 4.6–5.3)μ
1–septate, 9.6 x 5.1 (7.8–12.3 x 4.1–6)μ, the largest 8.8 x 6.1μ

On potato stem plug, culture one hundred and twelve days old:
(1) Conidia from a sporodochium

Conidia: 0–septate, 1 per cent
1–septate, rare
3–septate, 79 per cent, 36.4 x 4.1 (33–39 x 3.9–4.7)μ
4–septate, 13 per cent, 40 x 4.2 (36–42 x 3.9–4.4)μ
5–septate, 7 per cent, 40 x 4.3 (35–45 x 4–4.7)μ
6–septate, very rare, same size as 5–septate

(2) Chlamydospores, in conidia common, mostly 0–septate, 6.3 x 5.2 (5.1–8 x 4.3–6)μ

On whole steamed potato tuber, culture forty-nine days old; conidia from a sporodochium:

Conidia: 0–septate, 4 per cent
3–septate, 86 per cent, 36 x 3.7 (22–44 x 2.9–4.1)μ
4–septate, 8 per cent, 38 x 4.1 (35–43 x 3.9–4.2)μ
5–septate, 2 per cent, 40 x 4.1 (37–44 x 4.1)μ

On rye grain, culture sixty-three days old; conidia from a small sporodochium:

Conidia: 0–septate, 35 per cent
1–septate, 12 per cent
2–septate, 1 per cent
3–septate, 45 per cent, 34 x 4 (24–44 x 3.5–4.4)μ
4–septate, 5 per cent, 41 x 4.2 (36–47 x 4–4.7)μ
5–septate, 2 per cent, 45 x 4.3 (44–51 x 4–4.7)μ

On corn agar, culture one hundred and seventy-two days old; most of the conidia with chlamydospores:

(1) Pseudopionnotal conidia (only those without chlamydospores were measured)

Conidia: 3–septate, 32 x 4μ
4–septate, 35 x 4.1μ
5–septate, 37 x 4.2μ

(2) Chlamydospores in conidia very numerous, 0–septate predominant, 7.3 x 6.8 (6–10 x 5–9)μ

On hard lima-bean agar with 2 per cent glucose, culture one hundred and eighteen days old:

(1) Chlamydospores in conidia very numerous, 0–septate predominant, 7.2 x 5.7 (6–8 x 5.2–6)μ

(2) Sporodochial conidia

Conidia: 3–septate, 99 per cent, 33 x 4.2 (29–39 x 3.8–4.7)μ
4–septate, 1 per cent, 36 x 4.3 μ (only three measured)

On hard lima-bean agar, culture five days old; conidia from aërial mycelium (chlamydospores in conidia not observed):

Conidia: 0–septate, 46 per cent, about 11 x 2.6μ
1–septate, 4 per cent, about 16 x 3.1μ
2–septate, 1.5 per cent
3–septate, 48 per cent, 32 x 4 (23–41 x 3.5–4.3)μ
4–septate, 0.5 per cent, 35 x 4.1μ (only two measured)

On same medium as above, culture thirteen days old; conidia from aërial mycelium:

Conidia: 0–septate, 25 per cent
1–septate, 6 per cent
2–septate, 1 per cent
3–septate, 63 per cent, 35 x 4.2 (30–40 x 3.9–4.7)μ
4–septate, 5 per cent, 37.8 x 4.4 (33–41 x 4–4.7)μ

Average of the above measurements:

Conidia: 0–septate, 20 per cent 8.4 x 2.6μ
1–septate, 1.5 per cent, 15 x 3.2μ
2–septate, 3.5 per cent, 20 x 3.4μ
3–septate, 69 per cent, 33.9 x 4.07μ
4–septate, 5 per cent, 39.4 x 4.23μ
5–septate, 1 per cent, 41.1 x 4.32μ

37. *Fusarium lutulatum* var. **zonatum** n. var. (Pl. I, figs. 9 and 10; Pl. V, fig. 4)

Differs from *F. lutulatum* by slightly shorter and broader microconidia; usually by the absence of chlamydospores in conidia;[47] by conidia somewhat less pointed than those in *F. lutulatum*; by commoner production of aërial mycelium; and by more or less distinct zonation of colony growth on neutral agars. Spore color begins to develop earlier but usually does not reach the density of that of *F. lutulatum*. The organism does not produce rot of potato tubers, while *F. lutulatum*, at least in most of the inoculations made, is capable of causing such rot. No sclerotia observed.

Hab. On rotted tubers of *Solanum tuberosum* together with *F. oxysporum* var. *resupinatum* and *F. sanguineum*, at Ithaca, New York.

The size of the conidia is in many instances almost identical with that in *F. lutulatum*, and in general there is scarcely any very sharp distinction between the two organisms; but there are at least slight differences in many of the important characters, so that in general there can hardly be any serious doubt that these are two distinct, though closely related, organisms.

Average of the measurements of conidia on the same media, of the same age, and the same in other ways, as those of *F. lutulatum*, is as follows:

Conidia: 0–septate, 23 per cent, 9 x 2.8μ
1–septate, 5 per cent, 16 x 3.1μ
2–septate, 2 per cent, 22 x 3.5μ
3–septate, 69 per cent, 32.77 x 4.16μ
4–septate, 1 per cent, 39.4 x 4.4μ
5–septate, very rare, 39.3 x 4.6μ

38. **Fusarium sclerotioides** n. sp. (Figs. 10_1 and 33; Pl. I, figs. 11 and 12; Pl. V, fig. 1)

Macroconidia gradually attenuate toward and more or less pointed at the apex, pedicellate, generally somewhat more distinctly curved near apex, and broader in the middle or in the upper third of their length, typically 3–septate, 34.7 x 4.4 (30–39.5 x 4.1–4.6)μ, also 2– to 5–septate, 4– and 5–septate being of more or less common occurrence; chlamydospores observed only in mycelium (intercalary and terminal), and not very

[47] These were observed in number only once, and then when the culture was very old and much contaminated with bacteria. It was observed generally that a bacterial contamination greatly stimulates production of chlamydospores.

common nor numerous when compared with all the other species of section Elegans, usually only unicellular; aërial mycelium on hard agars invariably well developed, of medium height (from 2 to 4 millimeters) and density, very frequently forming macroscopically observable knots at the hyphal tips, finally, if the conditions are right, resulting in production of numerous small sporodochia; large (up to 12 millimeters in diameter), bluish black, shiny, more or less wrinkled, sclerotia are frequently produced on potato tuber plugs; the sclerotia in some cases overgrown with aërial mycelium, and then not so conspicuous; plectenchymic bodies (from 1 to 3 or more millimeters in diameter) wartlike in appearance,

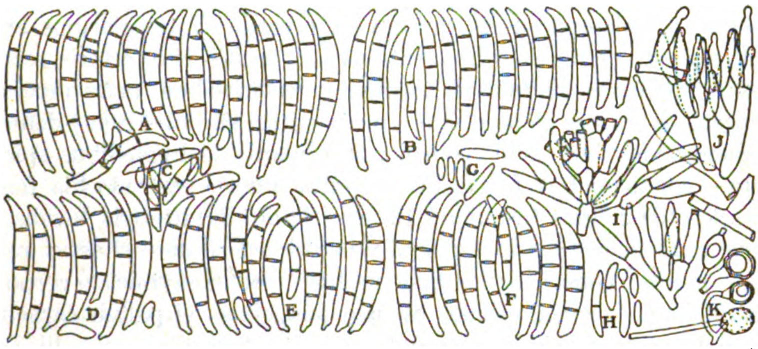

FIG. 33.—*Fusarium sclerotioides.* A, *Conidia from plectenchymic sporodochium from 14-days-old culture on potato tuber plug;* B, *conidia from plectenchymic sporodochium from 58-days-old culture on red raspberry cane plug;* C, *conidia from 24-days-old culture on slightly acidified hard potato agar;* D, *sporodochial conidia from 6-days-old culture,* E, *sporodochial conidia from 12-days-old culture,* F, *sporodochial conidia from 51-days-old culture, on hard lima-bean agar;* G, *microconidia from 13-days-old culture on hard lima-bean agar with 2 per cent glucose;* H, *microconidia from aërial mycelium,* I, *sporodochial conidiophores, from 58-days-old culture on red raspberry cane plug;* J, *conidiophore from 6-days-old culture on hard lima-bean agar;* K, *chlamydospores from 58-days-old culture on red raspberry cane plug*

white or pale flesh in color, often produced in considerable number and in some cases finally bearing masses of septate conidia; conidia, however, rarely produced on the sclerotia; color of the conidial mass somewhat variable, but usually of a tint of pinkish buff; color of substratum varying from nearly colorless when young to cinnamon red, deep vinaceous, and dark vinaceous purple. (For typical color when mature see Plate I, figure 12.)

Hab. On rotted tubers and in discolored fibrovascular bundles of tubers of *Solanum tuberosum* at Atlanta and Ithaca, New York, and in Louisiana.

Cultures of this organism on all media may for a long time produce microconidia almost exclusively; but if mature macroconidia from occasionally produced sporodochia are planted, macroconidia may be produced again in new cultures in great abundance and on almost any medium.

Latin description.—Macroconidiis gradatim in apicem attenuatis, apice acutis, pedicellatis plerumque aliquatenus distinctius ad apicem curvatis, medio latioribus vel superiore tertio longitudinis, typice 3–septatis, 34.7 x 4.4 (30–39.5 x 4.1–4.6)μ, vel etiam 2–5–septatis, plus minusve saepe 4–5–septatis; chlamydosporis tantum in mycelio (intercalaribus et terminalibus) sed nec maxime frequentibus nec multis prae ceteris sectionis Elegantis speciebus, plerumque tantum unicellularibus; aerio mycelio in duris agaribus semper plene maturo, mediocriter alto (2–4 mm.) densoque, saepissime nodos nudo oculo conspicuos formante in hyphalibus apicibus, demum — condicionibus faventibus — multa minuta sporodochia ferente; saepe sclerotiis magnis (usque ad 12 mm. diam.) livido–atris, lucidis, plus minusve rugosis, in tuberibus Solani tuberosi; sclerotiis — si aerio mycelio obsita — minus conspicuis; saepe multis plectenchymicis corporibus (1–3 mm. diam., vel majoribus), verrucoideis, albis vel pallide carneis, vel moles septatorum conidiorum vel nullas tandem ferentibus; conidiis autem in sclerotiis raro ortis; colore conidiorum molis aliquatenus variante, sed plerumque "pinkish buff" (R) tincto; colore substrati juvenis ferme hyalino dein "cinnamon rufous" (R), "deep vinaceous" (R), "dark vinaceous purple" (R). (Vide typicam colorem maturi substrati Tab. I, fig. 12.)

Hab. In putridis tuberibus et in decoloratis fibro-vascularibus fasciculis tuberum Solani tuberosi, Atlanta et Ithaca, New York, et Louisiana, Amer. bor.

Measurements of conidia on different media are as follows:

On red raspberry cane plug, culture fifty-eight days old; conidia from a sporodochium:

Conidia: 1–septate, 1 per cent
2–septate, 1.5 per cent
3–septate, 87 per cent, 30 x 4.4 (21–40 x 3–5.1)μ
4–septate, 9 per cent, 37 x 4.5 (33–41 x 4.1–5.1)μ
5–septate, 1.5 per cent, 40 x 4.6 (35–45 x 4.3–5.1)μ

On hard lima-bean agar with 2 per cent glucose, culture thirteen days old; conidia from aërial mycelium:

Conidia: 0–septate, 90 per cent, 9.5 x 2.25 (7–15.5 x 1.75–2.4)μ
1–septate, 10 per cent, 13.4 x 2.5 (12–18 x 2.3–3)μ

On corn meal agar, culture one hundred and seventy-three days old:

Chlamydospores: 0–septate, in mycelium, 8.5 x 8.2 (7–11.5 x 5–10.5)μ

On hard lima-bean agar, culture six days old; conidia from a sporodochium:

Conidia: 0–septate, rare
1–septate, very rare
3–septate, up to 100 per cent, 37 x 4.3 (31–41 x 3.9–4.4)μ
4–septate, rare, 37 x 4.4μ (only one measured)

On same medium as above, culture fifty-one days old; conidia from a medium-sized sporodochium:

Conidia: 0–septate, 1 per cent
1–septate, 1.5 per cent
3–septate, 73 per cent, 33 x 4.5 (23–39 x 3.5–4.8)μ
4–septate, 23 per cent, 37 x 4.5 (31–42 x 4–4.8)μ
5–septate, 1.5 per cent, 38 x 4.6 (31–42 x 4.2–4.9)μ

On same medium as above, culture twelve days old; conidia from pseudopionnotes:

Conidia: 0–septate, 6 per cent
1–septate, 3 per cent
2–septate, exceptional
3–septate, 74 per cent, 35 x 4.6 [(22–) 33–39 x (3.5–) 4.1–4.8]μ
4–septate, 16 per cent, 36 x 4.7 (33–42 x 4.4–4.8)μ
5–septate, 1 per cent, 37 x 4.7 (35–40 x 4.6–4.8)μ

On potato tuber plug, culture fourteen days old; conidia from a medium-sized sporodochium:

Conidia: 0–septate, 8 per cent
1–septate, 3 per cent
2–septate, rare
3–septate, 46 per cent, 35 x 4.1 (29–43 x 3–4.7)μ
4–septate, 29 per cent, 40 x 4.2 (31–47 x 3.5–4.7)μ
5–septate, 14 per cent, 40 x 4.3 (35–47 x 4–4.7)μ

On hard oat agar, culture twenty-four days old; conidia from a sporodochium:

Conidia: 3–septate, 64 per cent, 39.5 x 4.3 (36–52 x 4–4.7)μ
4–septate, 28 per cent, 41 x 4.3 (38–45 x 4–4.7)μ
5–septate, 8 per cent, 43 x 4.5 (38–46 x 4.1–4.7)μ

Average of the above measurements:

Conidia: 0–septate, 16 per cent, 9.5 x 2.25μ
1–septate, 3 per cent, 13.4 x 2.5μ
2–septate, rare
3–septate, 63 per cent, 34.7 x 4.4μ
4–septate, 15 per cent, 37.9 x 4.43μ
5–septate, 3 per cent, 39.35 x 4.55μ

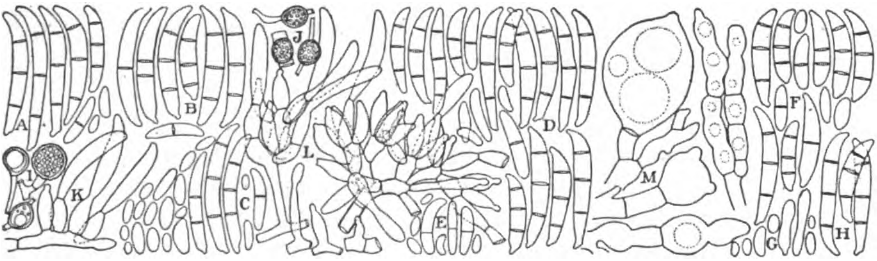

FIG. 34.—*Fusarium sclerotioides var. brevius.* A, *Pseudopionnotal conidia from 8-days-old culture on hard lima-bean agar;* B, *sporodochial conidia,* C, *conidia from aërial mycelium, from 19-days-old culture on slightly acidified hard potato agar;* D, *sporodochial conidia from 45-days-old culture on red raspberry cane plug;* E, *conidia from aërial mycelium from 13-days-old culture on hard lima-bean agar with 2 per cent glucose;* F, *sporodochial conidia,* G, *aërial conidia, from 60-days-old culture on whole steamed potato tuber;* H, *sporodochial conidia from 35-days-old culture on oats;* I, *chlamydospores from 45-days-old culture on red raspberry cane plug;* J, *chlamydospores from 25-days-old culture on corn agar;* K, L, *conidiophores from 19-days-old culture on slightly acidified hard potato agar;* M, *swollen tips of aërial hyphæ from 13-days-old culture on hard lima-bean agar with 2 per cent glucose*

39. *Fusarium sclerotioides* var. **brevius** n. var. (Fig. 34; Pl. II, figs. 1 and 2)

Differs from *F. sclerotioides* mainly by nearly constant absence of 4– and 5–septate conidia, by absence of large bluish black sclerotia, and by noticeably shorter, 3–septate conidia.

Hab. In discolored fibrovascular bundles of tubers of *Solanum tuberosum,* Alabama.

Measurements of the conidia on different media are as follows:

On red raspberry cane plug, culture forty-five days old; conidia from a plectenchymic sporodochium:

Conidia: 0–septate, 8 per cent, 15 x 3 (6–21 x 2.5–3.5)μ
1–septate, 17 per cent, 18 x 3.7 (17–23 x 3.5–4)μ
2–septate, 15 per cent, 20 x 4 (17–23 x 3.5–4.4)μ
3–septate, 60 per cent, 28.3 x 4.3 (19–39 x 3.5–4.8)μ
4–septate, rare

On slightly acidified hard potato agar, culture nineteen days old; conidia from a small sporodochium:

Conidia: 0–septate, rare
1–septate, rare
2–septate, 2 per cent, 24 x 4.2 (20–27 x 3.5–4.7)μ
3–septate, 98 per cent, 30.3 x 4.5 (21–37 x 4.1–4.8)μ

On hard lima-bean agar with 2 per cent glucose, culture thirteen days old; conidia from aërial mycelium:

Conidia: 0–septate, 98 per cent, 7.5 x 2.6 (4.3–18 x 2.3–3.7)μ
1–septate, 2 per cent, 13.5 x 3.2 (10–18 x 2.4–3.5)μ

On same medium as above, culture sixty-five days old; conidia from a sporodochium:

Conidia: 0–septate, 8 per cent, 6.4 x 2.8 (4.4–11 x 2.3–4.1)μ
1–septate, 5 per cent, 22 x 3.8 (15–29 x 3–4.3)μ
2–septate, 2 per cent, 24 x 4 (18–28 x 3.5–4.4)μ
3–septate, 85 per cent, 28 x 4.3 (24–35 x 3.7–4.8)μ

On corn meal agar, culture one hundred and seventy-three days old:

Chlamydospores: 0–septate, in conidia, 7.9 x 7 (5–11.5 x 5–9)μ
1–septate, in mycelium, 13.3 x 8.1 (11–18 x 7–9)μ

On hard lima-bean agar, culture eight days old; conidia from aërial mycelium:

Conidia: 0–septate, 55.5 per cent, 7.8 x 2.8 (5.2–13 x 2.1–3.9)μ
1–septate, 4 per cent, 13.3 x 3.2 (12–15 x 3–3.6)μ
2–septate, 0.5 per cent
3–septate, 40 per cent, 30.8 x 4.1 (23–37 x 3.9–4.2)μ

On same medium as above, culture twelve days old; conidia from pseudopionnotes:

Conidia: 0–septate, 12 per cent
1–septate, 3 per cent
2–septate, 2 per cent
3–septate, 83 per cent, 31 x 4.3 (22–41 x 4–4.7)μ
4–septate, exceptional, 41 x 4.4μ (only one measured)

On hard oat agar, culture twenty-four days old; conidia from a sporodochium:

3–septate, 100 per cent, 31.5 x 4.4 (23–35 x 3.8–4.7)μ

Average of the above measurements:

Conidia: 0–septate, 30.5 per cent, 9.2 x 2.8μ
1–septate, 5 per cent, 16.5 x 3.5μ
2–septate, 3.5 per cent, 22 x 4μ
3–septate, 61 per cent, 29.8 x 4.3μ
4–septate, very rare, 41 x 4.4μ

40. *Fusarium oxysporum* Schlecht.[48] (Figs. 1N$_1$ and 35A; Pl. v, fig. 6)

Schlechtendal, Fl. Berol., 2:139. 1824. Smith, E. F., and Swingle, D. B., U. S. Plant Indus. Bur., Bul. 55. 1904. Wollenweber, H. W., Phytopath. 3:28, fig. 1F. 1913. Wollenweber, H. W., Journ. Agr. Research 2:268. 1914.

Microconidia gradually pointed toward apex, nearly cylindrical in middle half of their length, typically not broader toward apex, usually somewhat distinctly pedicellate, 3-septate dominant, 30.4 x 4.2 (27.5–34 x 4–4.4)μ,[49] in sporodochia and pseudopionnotes; 4–septate macroconidia frequently, and 5–septate ones rarely, present; in mass usually of pinkish buff color; aërial mycelium typically well developed, of medium height (from 3 to 5 millimeters) and density, from white to (in spots on boiled rice) congo pink;

[48] Original description of *F. oxysporum* Schlecht. (see von Schlechtendal, Flora Berolinensis 2: 139) — "*F.* stroma convexum erumpens varium roseum superficie inaequali rugulosa, sporidiis parvis curvatis utrinque acutissimis"— is insufficient for identification of the species, and, short as it is, it sooner suggests some other species and not that of Smith and Swingle. For a detailed discussion of the matter see Appel and Wollenweber (1910: 144–146).

Wollenweber (1913 a: 28) gives his own description of *F. oxysporum* Schlecht., which, as he states (page 42 of reference cited), "includes some additions to the descriptions given by Smith and Swingle."

For the reason that, at least among pathologists and mycologists of the United States, this organism is fairly well known under this name, and after Wollenweber's description of it the meaning became definite and recognizable, the name *F. oxysporum* is retained here and is used for the organism described by Wollenweber without consideration of Schlechtendal's original description; that is, *F. oxysporum* here is as emended by Wollenweber.

[49] Wollenweber (1913 a: 28) gives the size variation as 25–45 x 3.25–4.5μ. Whether this is average or individual size variation is not stated.

substratum, on potato agar rich in glucose, vinaceous lilac, varying from colorless and orange vinaceous to pomegranate purple and vinaceous purple; plectenchymic sporodochia common on most of the media; bluish black sclerotia (up to 3 millimeters in diameter) constantly present on potato tuber plug and sometimes on different agars.

Hab. In fibrovascular bundles of diseased stems and tubers of *Solanum tuberosum*, in the United States, perhaps also in Europe, Africa, and other regions, also on *Lycopersicum esculentum* Vigna, and Pisum.

The organism was isolated alone and in association with several other Fusaria, several times from various localities in New York and in other States. The description given above is based on the study of the culture obtained through the courtesy of Dr. Wollenweber.

Measurements of the conidia are as follows:

On slightly acidified hard potato agar, culture nineteen days old; conidia from aërial mycelium close to substratum:

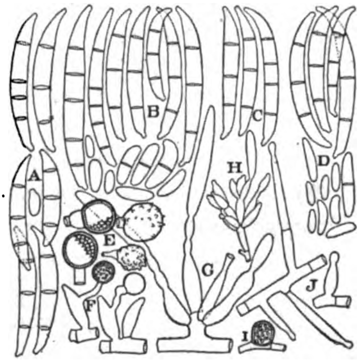

FIG. 35.— A, *Fusarium oxysporum*, *sporodochial conidia* B–J, *F. oxysporum var. asclerotium:* B, *Conidia from 14-days-old culture on slightly acidified hard potato agar;* C, *conidia from 46-days-old culture on red raspberry cane plug;* D, *conidia from 7-days-old culture on hard lima-bean agar;* E, *chlamydospores from 46-days-old culture on red raspberry cane plug;* F, *terminal chlamydospores produced on normal conidiophores,* G *and* H, *conidiophores* (H *magnified 250 times*) *from 14-days-old culture on slightly acidified hard potato agar;* I, *chlamydospores from 25-days-old culture on corn agar;* J, *conidiophores from 7-days-old culture on hard lima-bean agar*

Conidia: 0–septate, 87 per cent, 8 x 2.9 (4.5–12 x 2–4)μ
1–septate, 6 per cent, 16.5 x 3.4 (11–23 x 2.5–4.1)μ
2–septate, 1 per cent, 18.5 x 3.9 (17–26 x 3–4.2)μ
3–septate, 5 per cent, 27.5 x 4 (15–39 x 3–4.7)μ
4–septate, 1 per cent, about 40 x 4.5 (36–44 x 4.3–4.8)μ

On hard lima-bean agar, culture twelve days old; conidia from aërial mycelium:

Conidia: 0–septate, 99 per cent, 6.5 x 2.6 (4.5–16 x 1.75–3.5)μ
1–septate, 1 per cent, 14 x 3.2 (10–17 x 3–3.5)μ

On same medium as above, culture sixty-five days old:
(1) Conidia from a sporodochium

Conidia: 0–septate, 3 per cent
1–septate, 1 per cent
3–septate, 93 per cent, 33.8 x 4.3 (22–42 x 4–4.7)μ
4–septate, 3 per cent, 35.7 x 4.3 (33–41 x 4.1–4.7)μ
5–septate, rare, 35 x 4.4μ (only two measured)

(2) Chlamydospores, terminal and intercalary, 0–septate dominant

Chlamydospores: 0–septate, 8.7 x 8 (7–12.5 x 7–12.5)μ
1–septate, 15.5 x 9.2 (12–22 x 7.7–14)μ
Also in short chain, 2– and 3–septate, 2–septate commoner

On hard oat agar, culture twenty-three days old; conidia from a sporodochium:

Conidia: 3–septate, 93 per cent, 30 x 4.4 (26–35 x 3.9–4.7)μ
4–septate, 6 per cent, 34.5 x 4.5 (31–39 x 4.2–4.7)μ
5–septate, 1 per cent

On corn meal agar, culture one hundred and seventy-three days old; chlamydospores abundant, terminal and intercalary:

Chlamydospores: 0–septate, in conidia, 7.2 x 6.1 (6–9 x 4.8–8)μ
0–septate, in mycelium, 8.6 x 8 (7–10 x 7–11)μ
1–septate, often observed

On hard lima-bean agar, culture fifty days old; chlamydospores intercalary and terminal, in conidia and in mycelium, the latter most commonly observed:

Chlamydospores: 0–septate dominant, 8.9 x 7.3 (5.2–11 x 5.2–11)μ

Average of the above measurements of macroconidia:

Conidia: 3–septate, 0–93 per cent, 30.4 x 4.2μ
4–septate, 0–6 per cent, 36.7 x 4.43 (34.5–60 x 4.3–4.5)μ
5–septate, 0–rare, about 35 x 4.4μ

41. *Fusarium oxysporum* Schlecht. var. **asclerotium** n. var. (Fig. 35, B to J; Pl. v, fig. 7)

Differs from *F. oxysporum* mainly by absence of sclerotia and of definite plectenchymic sporodochia; differs also in color of mycelium and in somewhat longer and narrower macroconidia.

Hab. In rotted tuber of *Solanum tuberosum*, Atlanta, New York.

The organism was isolated from a flexible, semi-soft, rotted potato tuber late in the spring. No other organisms were associated with it. Very similar organisms were isolated also from discolored fibrovascular bundles of potato tubers from various States.

Average measurements of the conidia from four different cultures are as follows:

Conidia: 0–septate, 52.5 per cent, 7.9 x 2.6μ
1–septate, 8 per cent, 15 x 3.1μ
2–septate, rare
3–septate, 39 per cent, 34 x 4 (32–36 x 3.8–4.2)μ[50]
4–septate, 0.5 per cent, 37.5 x 4.35μ
5–septate, very rare, 37.5 x 4.35μ

Chlamydospores (on corn meal culture one hundred and seventy-three days old):
0–septate, in conidia, 7.7 x 7 (6.5–11 x 5–8)μ
0–septate, in mycelium, 9 x 8 (7–11 x 5–8)μ
1–septate, in mycelium, 14 x 9.5 (11–16.5 x 7–13.4)μ[51]

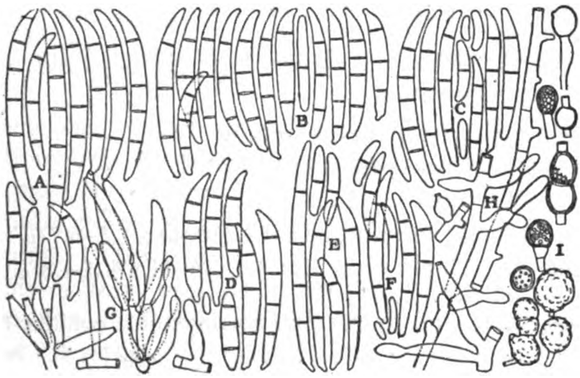

FIG. 36.— *Fusarium oxysporum var. longius.* A, *Pseudopionnotal conidia from 21-days-old culture on slightly acidified hard potato agar;* B, *conidia from 46-days-old culture on red raspberry cane plug;* C, *pseudopionnotal conidia from 5-days-old hard lima-bean agar;* D, *sporodochial conidia from 36-days-old culture on oat agar;* E, *pseudopionnotal conidia from 22-days-old culture on corn agar;* F, *conidia from 202-days-old culture on potato stem plug;* G, *conidiophores from 46-days-old culture on red raspberry cane plug;* H, *conidiophores from 5-days-old culture on hard lima-bean agar;* I, *chlamydospores from 202-days-old culture on potato stem plug*

[50] Variation of averages of at least ten spore measurements.
[51] Variation of individual spore measurements.

42. *Fusarium oxysporum* Schlecht. var. **longius** n. var. (Figs. $1M_1$ and 36) Differs from *F. oxysporum* and other varieties of the species by longer macroconidia, typically 3–septate, 38.94 x 4.04 (34–45 x 3.6–4.4)μ, often 4– and 5–septate; no sclerotia; no macroscopical sporodochia.

Hab. In discolored fibrovascular bundles of tubers of *Solanum tuberosum* and of wilted stems, in New York, California, Maryland, and Connecticut.

On slightly acidified hard potato agar, culture twenty-one days old:

(1) Conidia from pseudopionnotes

Conidia: 0–septate, 1.5 per cent, 10 x 3 (8–12 x 2.5–3.5)μ
1–septate, 3 per cent, 18 x 3.5 (14–21 x 3–4)μ
2–septate, 0.5 per cent
3–septate, 60 per cent, 42.7 x 4.1 (28–54 x 3.5–4.8)μ
4–septate, 26 per cent, 49 x 4.3 (42–58 x 4–4.8)μ
5–septate, 9 per cent, 51.4 x 4.6 (46–60 x 4.3–4.7)μ

(2) Chlamydospores, terminal and intercalary

Chlamydospores: 0–septate, 7–9 x 5–6μ

On red raspberry cane plug, culture forty-six days old; conidia from mycelium close to substratum:

Conidia: 0–septate, 1.7 per cent, 11 x 2.6μ
1–septate, 1 per cent, 19 x 3μ
2–septate, rare
3–septate, 93 per cent, 34 x 4.4 (19–44 x 3.5–5.7)μ
4–septate, 4.3 per cent, 40 x 4.6 (35–44 x 4.2–4.8)μ

On corn meal agar, culture twenty-two days old; conidia from surface of medium:

Conidia: 0–septate, 20 per cent
1–septate, 8 per cent
2–septate, 2 per cent
3–septate, 40 per cent, 45 x 3.6 (36–54 x 3.2–4.2)μ
$\left.\begin{array}{l}\text{4–septate, 20 per cent}\\ \text{5–septate, 10 per cent}\end{array}\right\}$ the largest 67 x 4μ

On hard lima-bean agar with 2 per cent glucose, culture thirteen days old; conidia from aërial mycelium:

Conidia: 0–septate, 50 per cent, 8.6 x 2.5 (5.2–15 x 2.2–3)μ
1–septate, 10 per cent, 17.5 x 2.9 (12–21 x 2.3–3.5)μ
2–septate, 0.5 per cent, 21 x 3.2μ (only three measured)
3–septate, 30 per cent, 35.6 x 4 (24–50 x 3.2–4.4)μ
4–septate, 8 per cent, 45 x 4.2 (40–51 x 3.9–4.7)μ
5–septate, 1.5 per cent, 47.5 x 4.3 (42–51 x 3.9–5.1)μ

On hard lima-bean agar, culture five days old; conidia from aërial mycelium:

Conidia: 0–septate, 56 per cent, 11 x 2.4μ (only four measured)
1–septate, 4 per cent, 18 x 3.3μ (only four measured)
2–septate, 1.5 per cent
3–septate, 37 per cent, 37 x 4 (26–47 x 3.8–4.4)μ
4–septate, 1 per cent, 43 x 4.3 (40–45 x 4–4.5)μ
5–septate, 0.5 per cent, 50 x 4.4μ (only three measured)

On corn meal agar, culture one hundred and seventy-three days old:

Chlamydospores: (1) 0–septate, in conidia, 8.4 x 6.8 (7–9 x 5–8)μ
(2) 0–septate, terminal, on mycelium, 10 x 9 (9–10.5 x 7.5–10.5)μ

On potato stem plug, culture two hundred and two days old:

(1) Conidia from aërial mycelium close to substratum

Conidia: 0–septate, 40 per cent
1–septate, 20 per cent
2–septate, 10 per cent
3–septate, 30 per cent, 34.3 x 3.9 (22–42 x 3.4–4.1)μ

(2) Chlamydospores, terminal and intercalary, in spores and mycelium

Chlamydospores: 0–septate, 8.9 x 6.8 (6.2–10 x 5.2–9)μ

On hard lima-bean agar, culture twelve days old; conidia from pseudopionnotes:

Conidia: 0–septate, 2 per cent
1–septate, 1 per cent
2–septate, rare
3–septate, 70 per cent, 44 x 4.3 (35–48 x 4–4.8)μ
4–septate, 23 per cent
5–septate, 4 per cent, 46 x 4.3 (40–53 x 4.1–5.2)μ

On hard oat agar, culture fourteen days old; conidia from pseudopionnotes:

Conidia: 0–septate, 4 per cent, 10 x 2.5μ
1–septate, 1 per cent
2–septate, rare
3–septate, 70 per cent, 44 x 4.04 (39–50 x 3.5–4.7)μ
4–septate, 20 per cent, 45 x 4.2 (41–50 x 4–4.7)μ
5–septate, 5 per cent, 49 x 4.46 (42–51 x 4.3–4.7)μ

Average of the above measurements:

Conidia: 0–septate, 24 per cent, 10 x 2.6μ
1–septate, 7 per cent, 17.5 x 3.2μ
2–septate, 1 per cent, 21 x 3.2μ
3–septate, 52 per cent, 38.94 x 4.04μ
4–septate, 12 per cent, 44.25 x 4.35μ
5–septate, 4 per cent, 48.7 x 4.4μ

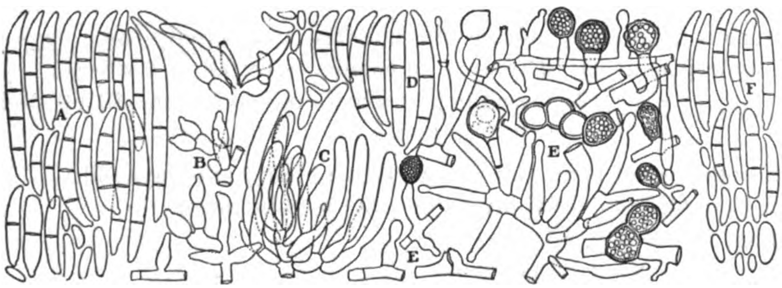

FIG. 37.—*Fusarium oxysporum var. resupinatum.* A, *Pseudopionnotal conidia from 15-days-old culture on slightly acidified hard potato agar;* B, *conidiophores from 6-days-old culture on hard lima-bean agar;* C, *conidiophore from 12-days-old culture on hard lima-bean agar;* D, *pseudopionnotal conidia from 6-days-old culture on hard lima-bean agar;* E, *conidiophores and chlamydospores,* F, *conidia, from 47-days-old culture on red raspberry cane plug*

43. *Fusarium oxysporum* Schlecht. var. **resupinatum** n. var. (Figs. 1L₁ and 37; Pl. I, figs. 7 and 8; Pl. V, fig. 5)

Differs from *F. oxysporum* by absence of sclerotia, from var. *asclerotium* and var. *longius* by shorter and somewhat narrower macroconidia. Mycelium on different agars typically entirely resupinate (Pl. I, figs. 7 and 8).

Hab. In discolored fibrovascular bundles of stem and tubers of *Solanum tuberosum*, United States.

This fungus and *F. oxysporum* var. *longius* are the organisms that were found very commonly present in discolored fibrovascular bundles of potato tubers and wilted plants. These organisms are also, as it seems, most commonly recognized by various pathologists as *F. oxysporum* Schlecht., as described by Smith and Swingle (1904); at least cultures of organisms undoubtedly belonging here were received under the name *F. oxysporum* from Mr. Wight in California, Dr. Taubenhaus in Delaware, and Dr. Clinton in Connecticut. The chief difference between these varieties of *F. oxysporum* of Smith and Swingle lies in the absence of sclerotia.

Measurements of spores on different media are as follows:

On slightly acidified hard potato agar, culture fifteen days old; conidia from thin pseudopionnotes:

Conidia: 0–septate, 74 per cent, 8 x 2.7 (5–15 x 2–4.3)μ
1–septate, 9 per cent, 21 x 3 (12–27 x 2.3–4.8)μ
2–septate, 4 per cent, 26 x 3 (20–37 x 2.2–4.1)μ
3–septate, 13 per cent, 35 x 4.2 (22–57 x 3.5–4.7)μ
4–septate, rare, 45 x 4.2μ

On red raspberry cane plug, culture forty-seven days old; conidia from aërial mycelium:

Conidia: 0–septate, 98 per cent, 6.5 x 2.7 (4.5–21 x 2.3–4.3)μ
1–septate, 2 per cent, 18 x 3.2 (12–24 x 2.8–4.1)μ
2–septate, rare, 22 x 3.4 (17–24 x 3–4.1)μ
3–septate, rare, 29 x 3.6 (19–36 x 3–4)μ

On hard lima-bean agar with 2 per cent glucose, culture fifteen days old; conidia from aërial mycelium:

Conidia: 0–septate, 97 per cent, 7.1 x 2.6 (5.2–16 x 1.8–4.3)μ
1–septate, 2 per cent, 16 x 3.1 (10–18 x 2.3–3.8)μ
2–septate, 0.5 per cent
3–septate, 0.5 per cent, 28 x 3.5 (23–36 x 2.4–4)μ

On corn meal agar, culture one hundred and seventy-three days old:

Chlamydospores: 0–septate, in conidia, 7.2 x 7 (5.8–9 x 5–8)μ
0–septate, in mycelium, 9.6 x 8.3 (7–16 x 7–11.5)μ
1–septate, in mycelium, 14.5 x 9.2 (13–18 x 7–11)μ

On hard lima-bean agar, culture six days old; conidia from pseudopionnotes:

Conidia: 0–septate, 82 per cent
1–septate, 5 per cent
2–septate, 2 per cent
3–septate, 11 per cent, 28 x 4.1 (22–36 x 3.9–4.7)μ

On the same medium as above, culture twelve days old; conidia also from pseudopionnotes;

Conidia: 0–septate, 15 per cent
1–septate, 8 per cent
3–septate, 77 per cent, 33.5 x 4.1 (29–37 x 4–4.5)μ; the smallest 21 x 3.4μ, the largest 40 x 4.5μ (both 3–septate)

Chlamydospores all kinds except terminal, 0–septate dominant, measuring 8.3 x 6.7 (6–10.5 x 5.2–8)μ

Average of the above measurements:

Conidia: 0–septate, 73 per cent, 7.2 x 2.7μ
1–septate, 5 per cent, 18 x 3.1μ
2–septate, 1.5 per cent, 24 x 3.2μ
3–septate, 20.5 per cent, 30.7 x 3.9μ
4–septate, rare, 45 x 4.2μ

X. Section Discolor Wr., Phytopath. 3:31, fig. 1, g, h, j, 1913

Conidia sickle-shaped, at the middle nearly cylindrical or broadened toward the apex, somewhat abruptly apically attenuated, distinctly pedicellate; mostly 3– to 5–septate, 5–septate dominant; microconidia typically absent; chlamydospores intercalary only, usually scant; mycelium typically well developed, with from nearly white to orange color as type. Substratum from nearly colorless to chamois, pomegranate purple, and spectrum red. Color of conidia very variable, mostly cinnamon to orange.

Differs from sections Elegans and Martiella by absence of microconidia, by the conidia being typically somewhat abruptly attenuate, by absence of terminal chlamydospores, and by absence of vinaceous, drab-gray, tawny-olive, and blue color of substratum. By the shape of conidia this section occupies an intermediate position between sections Elegans and Martiella; by its color it is closely related to sections Roseum and Ferruginosum.

44. *Fusarium trichothecioides* Wr. (Figs 1, u_1 and v_1, and 38; Pl. IV, fig. 8)

Jamieson, C. O., and Wollenweber, H. W., Journ. Washington Acad. Sci. 2:146–152, fig. 1. 1912.

Syn. *Fusarium tuberivorum* Wilcox and Link, Nebraska Agr. Exp. Sta., Research bul. 1 : 48. 1913.

Conidia of comma and discolor types, the former predominating and under ordinary cultural conditions occurring almost exclusively, mostly 1–septate, 16 x 4.6 (14–17 x 4.2–5.4)μ, often 0– to 3–septate, seldom 4– or 5–septate, 6–septate rare; sporodochial conidia sickle-shaped, 3– to 5–septate, 24–42 x 4.5–5.5μ.[52] Typical conidiopho es of *comma* stage shown in figure 38. Sporodochial conidiophores similar to those of *F. discolor*. *F. trichothecioides* can be recognized at once by color and appearance of its powdery masses of spores produced on aërial mycelium (Pl. IV, fig. 8). Chlamydospores few and not prominent.

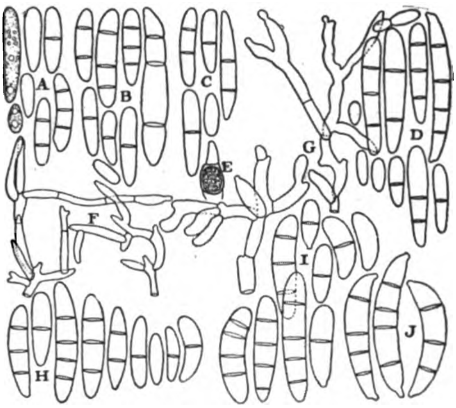

FIG. 38.—*Fusarium trichothecioides*. A, *Conidia from 41-days-old culture on rye straw;* B, *conidia from 70-days-old culture on potato stem plug;* C, *conidia from 73-days-old culture on red raspberry cane plug;* D, *conidia from 15-days-old culture on slightly acidified hard potato agar;* E, *chlamydospore in conidium from 73-days-old culture on red raspberry cane plug;* F, *conidiophores (magnified 250 times) from 70-days-old culture on potato stem plug;* G, *conidiophores from 15-days-old culture on slightly acidified hard potato agar;* H, *conidia from 5-days-old culture on hard lima-bean agar;* I, *comma,* J, *discolor, type of conidia from 5-days-old culture on potato tuber plug*

Hab. On rotted tubers of *Solanum tuberosum*, United States.

This species is noticeably different from all other species of the section Discolor. It is listed under this section chiefly because of its resemblance in the sporodochial form. Perhaps it should be made the type of a new section.

The organism, under the name *F. tuberivorum* Wilcox and Link, was

[52] The size of 3– to 5–septate conidia is as given by Wollenweber. The writer isolated this Fusarium from specimens of rotted potato tubers received from North Dakota in July, 1912, and from Texas in December, 1913. No special study of this organism was made at first, because it is easily recognizable even after a superficial examination, and also because its description as given by Wollenweber (see Jamieson and Wollenweber, 1912) is entirely sufficient for its identification.

extensively studied by Wilcox, Link, and Pool (1913). The identity of *F. tuberivorum* and *F. trichothecioides* Wr. is discussed by Wollenweber (1913 c:206). In the writer's opinion there is no doubt that this is correct. The few measurements of the conidia on different media are as follows:

On slightly acidified hard potato agar, culture fifteen days old:
Conidia: 0–septate, 23 per cent, 8.2 x 3.8 (5–15 x 3–4.7)μ
1–septate, 59 per cent, 19 x 4.2 (12–26 x 3.5–4.7)μ
2–septate, 8 per cent, 22.4 x 4.3 (16–35 x 4.3–5.2)μ
3–septate, 10 per cent, 28.1 x 5 (20–39 x 4.3–5.3)μ
4– and 5–septate, few, 40–45 x 5μ

On red raspberry cane plug, culture seventy-three days old:
Conidia: 0–septate, 39 per cent, 12 x 4.2 (7–14 x 3–4.8)μ
1–septate, 50 per cent, 14 x 4.3 (14–20 x 3.9–4.8)μ
2–septate, 11 per cent, 22 x 4.5 (19–32 x 4.1–5.2)μ

On potato tuber plug, culture five days old, kept at a low (from 3° to 7° C.) temperature:
Conidia: 0–septate, 6 per cent, 14 x 5.2 (10–17 x 4.8–5.5)μ
1–septate, 53 per cent, 16 x 5.4 (12–23 x 4.4–7)μ
2–septate, 15 per cent
3–septate, 19 per cent, 26 x 5.8 (19–42 x 5.2–7)μ
4–septate, 6 per cent, 35 x 6.2 (33–40 x 5.4–7)μ
5–septate, 1 per cent, 38 x 6.3 (31–52 x 5.4–7)μ
6–septate, exceptional, 41 x 6.3 (39–47 x 6–7)μ (only three measured)

Average of the above measurements:
Conidia: 0–septate, 23 per cent, 11 x 4.4μ
1–septate, 54 per cent, 16 x 4.6μ
2–septate, 11 per cent, 21 x 4.8μ
3–septate, 10 per cent, 27 x 5.4μ
4–septate, 2 per cent
5–septate, rare, 38 x 6.3μ
6–septate, very rare

45. **Fusarium subpallidum** n. sp. (Fig. 39; Pl. v, fig. 12)
Conidia sickle-shaped, typically abruptly constricted at apex, slightly pedicellate to papillate, somewhat broader in the middle, mostly 5–septate,

29.1 x 5.53 (28–32.5 x 5.4–5.8)μ, 3- and 4-septate common, 6- and 7-septate very rare; chlamydospores common, mostly in long chains; aërial mycelium well developed; plectenchymic sporodochia (up to 3 millimeters in diameter) common; color of aërial mycelium from white to sea-foam yellow and honey yellow; color of substratum, on agars rich in glucose, mostly from chamois to raw sienna and antique brown in some old cultures; color of conidia, in mass, commonly from pinkish buff to pale orange, sometimes from green to blue.[53]

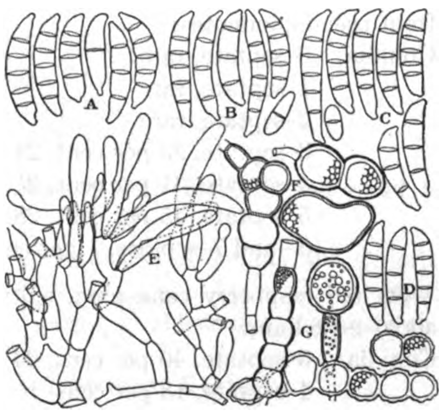

FIG. 39.—*Fusarium subpallidum.* A, *Sporodochial conidia from 70-days-old culture on hard potato agar;* B, *sporodochial conidia from 35-days-old culture on hard oat agar;* C, *conidia from a thin slimy layer from 15-days-old culture on slightly acidified hard potato agar;* D, *conidia from aërial mycelium from 52-days-old culture on red raspberry cane plug;* E, *conidiophores from 15-days-old culture on slightly acidified hard potato agar;* F, *chlamydospores from 175-days-old culture on corn agar;* G, *conidiophores from 52-days-old culture on red raspberry cane plug*

Hab. On superficial dry rot of tubers of *Solanum tuberosum.* The organism was isolated from rotted potato tubers received from Edgerton, Louisiana.

Latin description.—Conidiis falciformibus, typice subito apice constrictis, parum pedicellatis demum papillatis, medio aliquatenus latioribus, plerumque 5-septatis, 29.1 x 5.53 (28–32.5 x 5.4–5.8)μ, saepe etiam conidiis 3–4-septatis; conidiis 6–7-septatis rarissimis; chlamydosporis frequentibus plerumque longis catenulatis; aerio mycelio plene maturo; plectenchymicis sporodochiis (0–3 mm. diam.) frequentibus; aerio mycelio ex albo "sea-foam yellow" (R) vel "honey-yellow" (R); substrato, in agaribus perglucosis, plerumque e "chamois" (R) "raw sienna" (R) vel etiam in nonnullis culturis maturis "antique brown" (R); conidiis in totum plerumque e "pinkish buff" (R) pallide "orange" (R) vel interdum e viridi caeruleis.

[53] A very exceptional color for an organism of the section Discolor, and observed only in *F. subpallidum.* When the conidia are from green to blue in mass, some of them appear under the microscope very densely blue as if stained with methyl blue. The same was observed also in the case of *F. coeruleum, F. Martii,* and *F. Solani* var. *cyanum.*

Hab. In tuberibus aridis et extra putridis Solani tuberosi. Fungus e tuberibus Solani tuberosi putridis ab Edgerton in Louisiana, Amer. bor. receptis, sejungebatur.

Measurements of conidia on various media are as follows:

On slightly acidified hard potato agar, culture fifteen days old; conidia from pseudopionnotes:

Conidia: 0–septate, rare
1–septate, rare
2–septate, rare
3–septate, 23 per cent, 24.4 x 5.2 (16–30 x 4.7–5.7)μ
4–septate, 31 per cent, 25.6 x 5.5 (19–32 x 5.2–5.9)μ
5–septate, 45 per cent, 28 x 5.7 (24–34 x 4.7–5.9)μ
6– and 7–septate, 1 per cent, 31 x 6.1 (26–35 x 5.7–6.4)μ

On red raspberry cane plug, culture fifty-nine days old; conidia from aërial mycelium:

Conidia: 3–septate, 40 per cent, 24 x 4.7 (20–28 x 4.3–5)μ
4–septate, 18 per cent
5–septate, 42 per cent, 28 x 5.2 (24–31 x 5–5.3)μ (only four measured)

On hard potato agar, culture one hundred and seventy-five days old:

(1) Conidia from a sporodochium

Conidia: 3–septate, 4 per cent, 26 x 5.3 (23–28 x 5.2–5.4)μ
4–septate, 1 per cent
5–septate, 95 per cent, 29 x 5.8 (26–33 x 5.2–6.1)μ

(2) Chlamydospores

0–septate, in conidia, 8 x 7.5 (7–9 x 6–9)μ
1–septate, in mycelium, 15.5 x 10.3 (10–18 x 8.7–13.2)μ, the largest observed being 21 x 14μ

On medium soft potato agar, culture fifty days old:

(1) Conidia from thin pseudopionnotes

Conidia: 3–septate, 28 per cent, 25 x 5.4 (26–29 x 4.8—5.9)μ
4–septate, 23 per cent, about the size of 5–septate
5–septate, 49 per cent, 28 x 5.6 (24–32 x 5.2–6.3)μ

(2) Chlamydospores

0– and 1–septate, in clusters and chains, 7–16μ in diameter

On hard oat agar, culture twenty-three days old; conidia from sporodochium:

Conidia: 5–septate, 100 per cent, 32.5 x 5.4 (24–35 x 5.2–5.7)μ

Average of the above measurements:

Conidia: 0– to 2–septate, rare
3–septate, 19 per cent, 24.5 x 5.2μ
4–septate, 15 per cent, 25.6 x 5.5μ
5–septate, 66 per cent, 29.1 x 5.53μ
6– and 7–septate, very rare, 31 x 6.1μ

46. *Fusarium subpallidum* var. **roseum** n. var. (Fig. 1, S_1 and T_1; Pl. IV, fig. 3)

Differs from *F. subpallidum* by lower septation of conidia, the majority being 3–septate, 25.25 x 4.9 (22.5–27 x 4.7–5)μ, and by a tint or shade of from Tyrian rose to pomegranate purple in substratum on agars rich in glucose.

Hab. On rotted tubers of *Solanum tuberosum*, Kentucky.

Measurements of conidia on different media are as follows:

On slightly acidified hard potato agar, culture fifteen days old; conidia from pseudopionnotes:

Conidia: 0–septate, few
1–septate, 1 per cent, 17.5 x 4.7 (10–18 x 4.7)μ
2–septate, 1 per cent
3–septate, 44 per cent, 24.5 x 4.8 (18–29 x 4.7–5.3)μ
4–septate, 35 per cent, 27 x 4.9 (24–30 x 4.7–5.3)μ
5–septate, 19 per cent, 29 x 5.3 (24–32 x 4.7–5.7)μ

On red raspberry cane plug, culture seventy-three days old; conidia from a sporodochium:

Conidia: 0–septate, exceptional
1–septate } 1 per cent { 12 x 4.1 (10–14 x 3.8–4.4)μ
2–septate } { 23 x 4.8μ (only a few measured)
3–septate, 34 per cent, 26 x 5 (21–28 x 4.7–5.3)μ
4–septate, 35 per cent, 28 x 5.3 (23–30 x 4.8–5.7)μ
5–septate, 30 per cent, 30 x 5.3 (24–33 x 5–5.7)μ

On hard lima-bean agar, culture thirty-two days old; conidia from a sporodochium:

Conidia: 1–septate, 16 per cent
2–septate, 7 per cent
3–septate, 77 per cent, 22.5 x 4.8 (18–25 x 4.7–5.3)μ
4–septate, few, 26 x 5.1 (25–30 x 4.7–5.3)μ

On hard oat agar, culture twenty-three days old; conidia from a sporodochium:

Conidia: 3–septate, 90 per cent, 27 x 4.7 (24–34 x 4.1–4.9)μ
4–septate, 9 per cent, 29 x 4.9 (24–34 x 4.1–5.2)μ
5–septate, 1 per cent, 33 x 4.9 (30–40 x 4.8–5.2)μ

Average of the above measurements:

Conidia: 0–septate, rare
1–septate, 4.5 per cent, 17.5 x 4.7μ
2–septate, 2 per cent
3–septate, 61 per cent, 25.25 x 4.9μ
4–septate, 20 per cent, 27.5 x 5.1μ
5–septate, 12.5 per cent, 29.5 x 5.3μ

47. **Fusarium clavatum** n. sp. (Figs. 1R_1 and 40; Pl. III, figs. 11 and 12; Pl. VII, fig. 2)

Conidia sickle-shaped, typically distinctly broader in upper third of their length, somewhat suddenly constricted at the apex, slightly pedicellate, mostly 3– to 5–septate, 5–septate measuring 36.2 x 5.05 (32–46 x 4.8–5.2)μ; aërial mycelium of a medium development (2 to 4 millimeters high, more or less loose) to nearly absent, and then substratum covered with pseudopionnotes; chlamydospores scant, not in long chains; color of aërial mycelium and substratum from white to light pink and that shown on Plate III, figures 11 and 12; color of pseudopionnotes from pale pink to deep olive-buff and chocolate brown (Pl. III, fig. 11); color of sporodochia bright orange (Pl. VII, fig. 2).

Hab. On rotted tubers of *Solanum tuberosum*, together with *F. coeruleum*, Castile, New York.

Latin description.—Conidiis falciformibus, typice distincte latioribus in superiore tertio longitudinis, apice aliquatenus subito constrictis, parum pedicellatis, plerumque 3–5–septatis, 5–septatis, 36.2 x 5.05 (32–46 x 4.8–5.2)μ; aerio mycelio mediocriter maturo (2–4 mm. alt., plus minusve laxo)

vel ferme nullo, quae cum ita sint substrato pseudopionnotibus obsito; chlamydosporis paucis, non catenulatis; aerio mycelio substratoque ex albo pallide rubello vel eodem colore quod in Tab. III, figg. 11, 12, exhibente; pseudopionnotibus e pallide rubello "olive-buff" (R) et "chocolate brown" (R); sporodochiis nitide "orange" (R).

Hab. In tuberibus putridis Solani tuberosi una cum F. coeruleo, Castile, New York, Amer. bor.

Measurements of conidia on various media are as follows:

On red raspberry cane plug, culture ninety-two days old; conidia from pseudopionnotes:

Conidia: 3–septate, 5 per cent, 27 x 4.2 (20–35 x 4–4.7)μ
5–septate, 95 per cent, 35 x 4.8 (29–39 x 4.3–5.7)μ

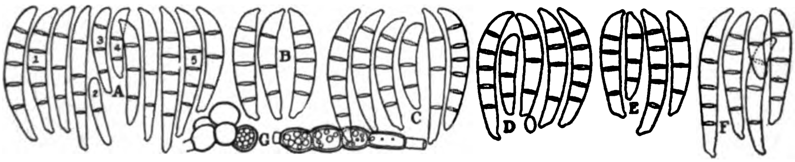

FIG. 40.—*Fusarium clavatum.* A, *Conidia from a thin layer near substratum from 92-days-old culture on red raspberry cane plug (conidia 1 and 5 are typical, but in certain areas conidia like 2, 3, and 4 were present almost to the exclusion of the other kinds);* B, *conidia from thin layer from 120-days-old culture on potato stem plug;* C, *pseudopionnotal conidia from 41-days-old culture on rye straw;* D, *pseudopionnotal conidia from 32-days-old culture on hard oat agar;* E, *pseudopionnotal conidia from 10-days-old culture on potato agar;* F, *pseudopionnotal conidia from 9-days-old culture on hard lima-bean agar;* G, *chlamydospores from 10-days-old culture on potato agar*

On hard lima-bean agar with 2 per cent glucose, culture twenty-two days old; conidia from aërial mycelium:

Conidia: 3–septate, 60 per cent, 26 x 4.9 (19–38 x 4.3–5.3)μ
4–septate, 16 per cent, 32 x 5.2μ (only one measured)
5–septate, 24 per cent, 32 x 5.15 (29–36 x 4.7–5.3)μ

On medium soft potato agar, culture ten days old; conidia from aërial mycelium (chlamydospores intercalary, in chains and clusters):

Conidia: 1–septate, 1 per cent, 16 x 4.4μ (only three measured)
3–septate, 82 per cent, 26 x 5 (23–31 x 4.7–5.4)μ
4–septate, 9 per cent, 29 x 5.1 (28–32 x 4.7–5.3)μ
5–septate, 8 per cent, 32 x 5.2 (29–34 x 4.7–5.3)μ

On hard lima-bean agar, culture nine days old; conidia from aërial mycelium close to substratum:

Conidia: 1–septate, very rare
2–septate, very rare
3–septate, 33 per cent, 30 x 4.6 (19–34 x 4.3–4.8)μ
4–septate, 23 per cent
5–septate, 44 per cent, 36 x 5 (33–40 x 4.6–5.4)μ

On same medium as above, culture fifteen days old; conidia from pseudopionnotes:

Conidia: 2–septate, very rare
3–septate, 36 per cent, 33 x 5 (22–39 x 4.6–5.3)μ
4–septate, 22 per cent
5–septate, 42 per cent, 36.5 x 5.1 (33–41 x 4.9–5.3)μ

Average of the above measurements:

Conidia: 1–septate, rare, 16 x 4.4μ
2–septate, very rare
3–septate, 43 per cent, 28.5 x 4.75μ
4–septate, 15 per cent
5–septate, 42 per cent, 36.2 x 5.05μ

48. *Fusarium discolor* Ap. et Wr. (Fig. 1Q₁ and 41; Pl. IV, fig. 4; Pl. V, fig. 11)

Appel, O. and Wollenweber, H. W., Arb. K. biol. Anst. Land– u. Forstw. 8:108–115; Pl. I, figs. 50 to 59; Pl. III, fig. 7. 1910.

Conidia for greater part of their length of nearly even diameter, sickle-shaped, gradually attenuated, often somewhat suddenly constricted at the apex, pedicellate, mostly 3– to 5–septate, 5–septate measuring 38.7 x 5.1 (35–40 x 4.6–5.1)μ,[54] on aërial mycelium, in pseudopionnotes, and in plectenchymic sporodochia; chlamydospores scant, not in long chains; aërial mycelium from poorly to well developed, from pale pink-buff to ochraceous orange and Eugenia red; color of substratum, on agars rich in glucose, from pale salmon at an early stage and warm sepia in old cultures to tyrian and ox blood; color of conidia mostly from light ochraceous salmon to ochraceous buff.

[54] Size of 5–septate conidia according to Wollenweber's data (see Appel and Wollenweber 1910 : 111–112) is 36 x 5.1 (29–39 x 4.5–5.5)μ. The writer's measurements were taken from cultures of the same organism. Average size of *F. discolor* strain isolated in United States is, for 3–septate conidia, 30.2 x 4.4μ (from 25 to 98 per cent), and for 5–septate conidia, 38.4 x 4.85 (33.5–44 x 4.5–5)μ (from 0 to 53 per cent).

Hab. In stems and rotten tubers of *Solanum tuberosum*, in Germany and in the United States.

Differs from *F. clavatum* mainly by indistinctly clavate conidia and by presence of denser hues of red color in substratum.

Measurements of conidia on various media are as follows:

On slightly acidified hard potato agar, culture twenty-four days old; conidia from pseudopionnotes:

Conidia: 1–septate, rare
3–septate, 11 per cent, 32.3 x 4.3 (27–37 x 4.1–4.9)μ
4–septate, 14 per cent, 36 x 4.5 (32–42 x 4.3–5)μ
5–septate, 75 per cent, 39.2 x 4.7 (31–46 x 4.3–5.7)μ
6–septate, few, 53 x 5.8μ (only one measured)

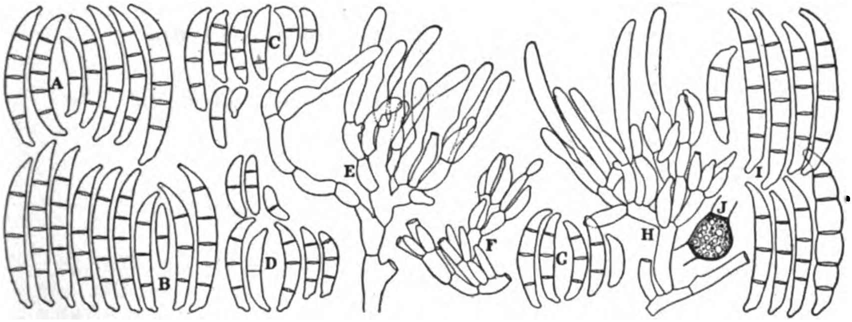

FIG. 41.—*Fusarium discolor.* A, *Conidia from a small plectenchymic sporodochium;* B, *conidia from pseudopionnotes from 15-days-old culture on slightly acidified hard potato agar;* C, *conidia from 81-days-old culture on red raspberry cane plug;* D, *conidia from 36-days-old culture on potato stem plug;* E, *conidiophores from aërial mycelium from 81-days-old culture on red raspberry cane plug;* F, *conidiophores from minute sporodochia from 36-days-old culture on potato stem plug;* G, *conidia from mycelial growth from 41-days-old culture on rye straw;* H, *conidiophore from pseudopionnotes from 15-days-old culture on slightly acidified hard potato agar;* I, *pseudopionnotal conidia from 9-days-old culture on hard lima-bean agar;* J, *intercalary chlamydospore from culture on corn agar*

On red raspberry cane plug, culture seventy-two days old; conidia from minute sporodochia on aërial mycelium:

Conidia: 1– and 2–septate, rare
3–septate, 27 per cent, 30 x 4.4 (19–49 x 3.7–4.8)μ
4–septate, 24 per cent, 36 x 4.6 (26–49 x 3.9–5.9)μ
5–septate, 49 per cent, 40 x 5.2 (32–50 x 4.9–5.9)μ

On potato tuber plug, culture ninety-nine days old; conidia from a sporodochium:

Conidia: 3–septate, 6 per cent, 26 x 4.7 (22–30 x 4.3–4.8)μ
4–septate, 25 per cent, 33 x 5 (28–40 x 4.6–5)μ
5–septate, 69 per cent, 35 x 5.2 (28–42 x 4.7–5.7)μ

On hard lima-bean agar with 2 per cent glucose, culture fifty-four days old; conidia from a small sporodochium:

Conidia: 1– to 3–septate, rare
4–septate, 2 per cent, 36 x 4.9μ (only two measured)
5–septate, 98 per cent, 40 x 5.2 (33–44 x 4.6–5.5)μ

On hard lima-bean agar, culture thirty-four days old; conidia from pseudopionnotes:

Conidia: 1–septate, very rare
3–septate, 49 per cent, 33.5 x 4.8 (24–44 x 4.1–6)μ
4–septate, 31 per cent
5–septate, 20 per cent, 39.3 x 5.1 (31–47 x 4.6–6.2)μ

Average of the above measurements:

Conidia: 1–septate, very rare
2–septate, very rare
3–septate, 19 per cent, 30.5 x 4.55μ
4–septate, 19 per cent
5–septate, 62 per cent, 38.7 x 5.1μ
6–septate, very rare, 53 x 5.8μ

49. *Fusarium discolor* Ap. et Wr. var. *sulphureum* (Schlecht.) Ap. et Wr. (Pl. IV, fig. 11)

Cf. Schlechtendal, Fl. Berol. **2**:134. 1824. Appel, O., and Wollenweber, H. W., Arb. K. biol. Anst. Land- u. Forstw. **8**:115–118. 1910.

Differs from *F. discolor* by absence of red color in mycelium and substratum, and by entirely exposed pseudopionnotes on various agars, a characteristic culture of which is shown in Plate IV, figure 11.

Average percentage of different septation types and sizes of conidia on three different media are as follows:

Conidia: 1–septate, about 0.5 per cent
2–septate, very rare
3–septate, about 25 per cent, 28.5 x 4.2μ

4–septate, about 28 per cent
5–septate, about 46.5 per cent, 40 x 4.9 (38–41 x 4.8–4.9)μ
6–septate, rare, 48 x 5.2μ

50. *Fusarium discolor* Ap. et Wr. var. **triseptatum** n. var. (Figs. $1w_1$ and 42; Pl. IV, figs. 5 and 6; Pl. V, fig. 10)

Differs from *F. discolor* by dominance of 3–septate conidia 24.2 x 4.7 (22–26 x 4.5–4.9)μ, by presence of very large (up to 1.2 centimeters in diameter), warty, plectenchymic bodies (producing conidia or remaining sterile) of a pale pinkish buff with spots of a darker color, by more intense color of mycelium and substratum (see Plate IV, figures 5 and 6), and by production of larger sporodochia with darker spore masses, much the same as shown for *F. culmorum* var. *leteius* in Plate IV, figure 10.

Hab. On rotted tubers of *Solanum tuberosum* together with *F. coeruleum*, Long Island, New York.

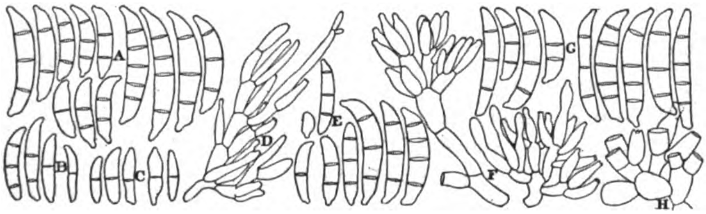

FIG. 42.— *Fusarium discolor var. triseptatum.* A, *Conidia from minute aërial sporodochia from 22-days-old culture on slightly acidified hard potato agar;* B, *conidia from 66-days-old culture on potato stem plug;* C, *conidia from aërial mycelium from culture on rye straw;* D, *conidiophore from aërial mycelium from 66-days-old culture on potato stem plug;* E, *conidia from plectenchymic sporodochia,* F, *conidiophores, from 22-days-old slightly acidified hard potato agar;* G, *conidia from plectenchymic sporodochia from 9-days-old culture on hard lima-bean agar;* H, *basal part of aërial compound conidiophore from 73-days-old culture on red raspberry cane plug*

Measurements of conidia on a few different media are as follows:

On slightly acidified hard potato agar, culture twenty-two days old; conidia from minute sporodochia on aërial mycelium:

Conidia: 0–septate, rare
1–septate, 1.6 per cent, 16 x 3.9μ
2–septate, 6.4 per cent, 18.5 x 4.3 (17–21 x 3.9–4.7)μ
3–septate, 91.2 per cent, 22.5 x 4.5 (17–39 x 3.9–5.7)μ
4–septate, 0.8 per cent
5–septate, very rare, 31 x 5.3 (28–35 x 5.2–5.8)μ

On red raspberry cane plug, culture seventy-three days old; conidia from a sporodochium:

Conidia: 0–septate, very rare
1–septate, 2 per cent, 15 x 3.7 (10–20 x 3–4.2)μ
2–septate, 8 per cent, 20 x 4.1 (17–23 x 3.6–4.7)μ
3–septate, 88 per cent, 24 x 4.6 (17–29 x 3.9–5.3)μ
4–septate, 2 per cent, 28 x 5.2 (25–30 x 4.8–5.7)μ

On hard lima-bean agar, culture nine days old; conidia from a young plectenchymic sporodochium:

Conidia: 1–septate, 2 per cent
2–septate, 3 per cent, 20 x 4.5 (13–25 x 4.1–4.7)μ
3–septate, 88 per cent, 26 x 4.9 (18–33 x 4.2–6)μ
4–septate, 6 per cent
5–septate, 1 per cent, 30 x 5.8μ (only a few measured)

Average of the above measurements:

Conidia: 0–septate, very rare
1–septate, 2 per cent, 15.5 x 3.8μ
2–septate, 6 per cent, 19.5 x 4.3μ
3–septate, 89 per cent, 24.2 x 4.7μ
4–septate, 3 per cent, 29.5 x 5.25μ
5–septate, few, 30.5 x 5.55μ

The organism seems to be so different from *F. discolor* that one may wonder why it is considered as a variety rather than an independent species, especially in view of the fact that there are some organisms designated as species which apparently differ very slightly from the other related species. The explanation lies mainly in the fact that, notwithstanding a seemingly great difference, this difference is in unstable characters — greater proportion of one type of septation instead of another, denser color, larger sporodochia, and so forth — and, moreover, in certain instances the two organisms approach each other so closely as to be distinguished only with considerable difficulty if at all.

51. *Fusarium culmorum* (W. Smith) Sacc. (Pl. IV, fig. 9; Pl. V, fig. 8)

Cf. Wollenweber, H. W., Journ. Agr. Research 2:260–261, Pl. XVI, fig. J. 1914.

Syn. *Fusarium culmorum* W. G. Smith, Dis. Field and Gard. Crops, pp. 208–210, fig. 92. 1884.

Fusarium Schribauxi Delacr., Bul. Soc. Mycol. France 6:99, pl. 15, fig. 1. 1890. Saccardo, Syll. Fung. 10:726. 1890.

Fusarium culmorum (W. Sm.) Sacc., Syll. Fung. 11:651. 1895.

Fusarium corallinum Mattirolo (non Sacc.), Mem. R. Accad. Sci. Ist. Bologna, ser. 5:6:677, figs. 16 and 17. 1897.

Fusarium rubiginosum Ap. et Wr., Arb. K. biol. Anst. Land- u. Forstw. 8:95–108; text fig. 8; Pl. I, figs. 31 to 48. 1910.

Conidia for a greater part of their length of an even diameter, mostly 5–septate, 38.5 x 5.85 (37–40 x 5.3–6.2)μ, somewhat suddenly constricted at apex; pedicellate, of distinctly ochraceous orange color under microscope; chlamydospores of more or less common occurrence in mycelium and in conidia, not in long chains; aërial mycelium well developed, high (up to 1 centimeter and more), very loose, at first from white to pinkish cinnamon, and then to jasper and Eugenia red; substratum, on potato agar rich in glucose, of from spectrum red to carmine-pomegranate purple, with more or less brick red color; color of conidia in mass from cinnamon and light ochraceous to mikado brown and warm sepia; sporodochia minute, separate or converging into pseudopionnotes.

Hab. On cereals and on potato tubers and some other hosts, in Europe and the United States.

The organism was isolated by the writer from rotted potato tubers, alone and in association with other Fusaria.

Measurements of conidia on different media are as follows:[55]

On slightly acidified hard potato agar, culture twenty-three days old; conidia from pseudopionnotes:

Conidia: 3–septate, 5 per cent, 33 x 5.9 (21–36 x 4.7–6.1)μ
4–septate, 10 per cent, 35 x 6.1 (30–37 x 5.7–6.4)μ
5–septate, 85 per cent, 37 x 6.2 (32–46 x 5.2–6.5)μ

On red raspberry cane plug, culture seventy-two days old:

(1) Conidia from a sporodochium

Conidia: 3–septate, 3 per cent
4–septate, 10 per cent
5–septate, 87 per cent, 40 x 6.2 (33–53 x 5.8–7)μ

[55] Average of the measurements given by Appel and Wollenweber (1910:106) is as follows.
Conidia: 0- to 2–septate, about 1 per cent
3–septate, about 11 per cent, 26 x 5.5μ
4–septate, about 13 per cent, 27 x 5.7μ
5–septate, about 74 per cent, 39 x 6.1μ
6–septate, about 1 per cent, 45 x 6μ

(2) Conidia from aërial mycelium

Conidia: 3–septate, 60 per cent, 30 x 4.7 (19–39 x 4.1–5.9)μ
4–septate, 25 per cent, 37 x 5 (31–42 x 4.4–5.9)μ
5–septate, 15 per cent, 39 x 5.3 (35–43 x 5.2–5.9)μ

On hard lima-bean agar with 2 per cent glucose, culture one hundred and fifty-four days old; conidia from pseudopionnotes:

Conidia: 0–septate, rare, 8 x 4μ (only a few measured)
1–septate, rare, 12 x 3.7μ (only a few measured)
2–septate, rare
3–septate, 3 per cent, 26 x 4.7 (17–34 x 4.1–5.5)μ
4–septate, 7 per cent
5–septate, 89 per cent, 38 x 5.7 (33–47 x 5.2–6.1)μ
6–septate, 1 per cent, 49 x 5.7μ (only a few measured)
7–septate, very rare, 56 x 6.1μ (only a few measured)

Average of the above measurements:

Conidia: 0–septate, very rare, 8 x 4μ
1–septate, very rare, 12 x 37μ
2–septate, very rare
3–septate, 18 per cent, 29.67 x 5.1μ
4–septate, 13 per cent
5–septate, 69 per cent, 38.5 x 5.85μ
6–septate, few, 49 x 5.7μ
7–septate, exceptional, 56 x 6.1μ

52. *Fusarium culmorum* (W. Smith) Sacc. var. **leteius** n. var. (Figs. 1D$_2$ and 43; Pl. IV, figs. 1, 2, 10; Pl. V, fig. 9)

Differs from *F. culmorum* mainly by somewhat comma-like conidia from aërial mycelium, by typical presence of medium large (up to from 3 to 5 millimeters in diameter) sporodochia, and by somewhat broader average size of conidia.

Hab. On rotted tubers of *Solanum tuberosum*, Atlanta and Forks, New York.

Measurements of conidia on different media are as follows:

On slightly acidified hard potato agar, culture fifteen days old; conidia from a sporodochium:

Conidia: 1–septate, 0.5 per cent, 18 x 5.2 (14–22 x 4.7–5.9)μ
2–septate, 5.5 per cent, 23 x 6.9 (20–26 x 6.4–7.9)μ
3–septate, 34 per cent, 26.5 x 7 (21–33 x 5.6–7.6)μ
4–septate, 38 per cent, 33.2 x 7.3 (26–38 x 6.4–7.9)μ
5–septate, 22 per cent, 36.4 x 7.5 (31–44 x 7–8.8)μ
6–septate, very few, 44.5 x 8.9μ (only one measured)

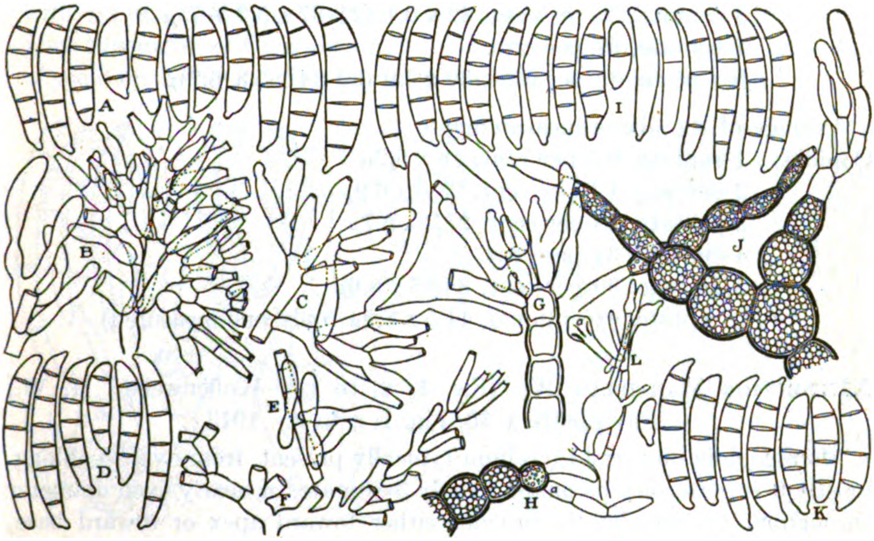

FIG. 43.— *Fusarium culmorum var. leteius.* A, *Conidia,* B, *conidiophores, from aërial sporodochium from 15-days-old culture on slightly acidified hard potato agar;* C, *conidiophore from 11-days-old culture on hard lima-bean agar;* D, *conidia from plectenchymic sporodochium,* E, F, G, *conidiophores, from 72-days-old culture on red raspberry cane plug;* H, *intercalary chlamydospores from 175-days-old culture on corn agar;* I, *conidia from plectenchymic sporodochium from 11-days-old culture on hard lima-bean agar;* J, *intercalary chlamydospores from 175-days-old culture on corn agar (some chlamydospores producing conidiophores);* K, *conidia from aërial sporodochia from 72-days-old culture on red raspberry cane plug;* L, *tip of aërial hypha showing prominent swellings (magnification 250 times)*

On red raspberry cane plug, culture seventy-two days old:

(1) Conidia from a plectenchymic sporodochium borne directly on the plug

Conidia: 3–septate, 14 per cent
4–septate, 20 per cent
5–septate, 66 per cent, 43 x 6.2 (31–53 x 5.8–7)μ

(2) Conidia from a bushlike sporodochium borne on aërial mycelium

Conidia: 1– and 2–septate, very few
3–septate, 40 per cent, 29 x 6.9 (26–35 x 6–7.8)μ
4–septate, 30 per cent, 32 x 6.8 (29–36 x 6–7.5)μ
5–septate, 30 per cent, 37 x 6.8 (31–42 x 6.3–7.5)μ

On hard lima-bean agar, culture eleven days old; conidia from a sporodochium (only mature spores measured):

Conidia: 1–septate, 2 per cent
3–septate, 26 per cent, 32 x 6.1 (24–37 x 5.2–6.7)μ
4–septate, 37 per cent
5–septate, 35 per cent, 39 x 5.9 (30–44 x 5.3–6.7)μ

Average of the above measurements:

Conidia: 1–septate, 0.5 per cent, 18 x 5.2μ
2–septate, 1.5 per cent, 23.5 x 6.9μ
3–septate, 28 per cent, 27.2 x 6.7μ
4–septate, 31 per cent
5–septate, 39 per cent, 38.85 x 6.6μ
6–septate, exceptional, 44.5 x 8.9μ (only one measured)

XI. SECTION MARTIELLA Wr. (Fig. 1, X_1 to C_2). Wollenweber, H. W., Phytopath. 3:30, Fig. 1, A to C. 1913

Microconidia on aërial mycelium typically present, from oval to oblong, mostly 0–septate; macroconidia mostly 3–septate, of nearly even diameter throughout or but slightly broader either toward apex or toward base, nearly straight in lower half and more or less curved near apex, with somewhat rounded apex or only slightly pointed or constricted, typically from slightly pedicellate to apedicellate; aërial mycelium mostly from white to a light tint of chamois and drab hues; substratum, on neutral agars, never rose-pink nor pomegranate purple in color, sometimes from vinaceous to blue; color of conidia, except in acid media, mostly from pale buff to drab, often distinctly from green to blue.

53. *Fusarium Martii* Ap. et Wr. (Figs. 1, Z_1 and A_2, and 44M)

Appel, O., and Wollenweber, H. W., Arb. K. biol. Anst. Land- u. Forstw. 8:78–84, text fig. 5. 1910.

Macroconidia mostly 3–septate, 43.9 x 5.15 (42–46 x 4.9–5.3)μ, and

4–septate, 49.3 x 5.3 (48–50 x 4.9–5.4)μ, often also 5–septate, typically, when mature, of from deep lichen and montpellier green (on corn meal agar) to light olive-drab (on potato agar rich in glucose) and often to dark blue (on potato tuber plug);[56] macroconidia usually produced in abundance in small sporodochia and in pseudopionnotes; chlamydospores terminal and intercalary, single, in clusters, and in short chains, mostly 0–septate, 9.25 x 8.16 (8–11.3 x 7.5–9.3)μ; aërial mycelium typically medium short (from 1 to 4 millimeters), loose, more or less coarsely powdered with conidia, and typically, on potato agar rich in glucose, of from smoke gray to sometimes Chartura drab color; the substratum on the same kind of medium being mostly of from tawny olive to sepia in color.

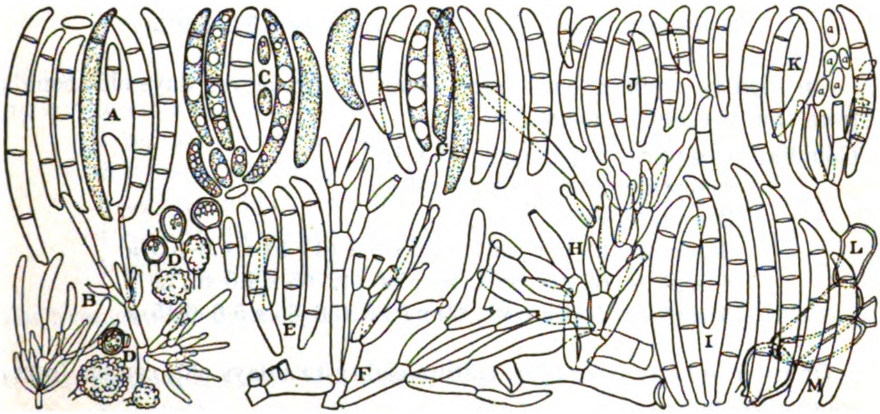

FIG. 44.— A-I, *Fusarium Martii var. viride.* A, *Pseudopionnotal conidia (the stippled one showing dense granulation of the protoplasm masking septation),* B, *conidiophores (magnification 250 times), from 11-days-old culture on slightly acidified hard potato agar;* C, *conidia showing dense granulation of the protoplasm containing from small to large oil globules from 29-days-old culture on rye straw;* D, *chlamydospores, terminal and intercalary,* E, *pseudopionnotal conidia, from 71-days-old culture on potato tuber plug;* F, *conidiophore from 70-days-old culture on potato stem plug;* G, *conidia,* H, *conidiophore, from 47-days-old culture on stem plug;* I, *pseudopionnotal conidia from 64-days-old culture on potato tuber plug*

J-L, *Fusarium Martii var. minus.* J, *conidia from plectenchymic sporodochium from 71-days-old culture on potato tuber plug;* K, *sporodochial conidia from 85-days-old culture on red raspberry cane plug;* Ka, *microconidia from aërial mycelium;* L, *basal part and one branch of compound conidiophore from 71-days-old culture on potato stem plug*

M, *Fusarium Martii, pseudopionnotal conidia from 11-days-old culture on slightly acidified hard potato agar*

[56] The culture media are mentioned here merely because the colors were oftener observed on these media than on others; in fact, a green color in conidia is often produced also on potato tuber plugs and on some other media, and the same is true of a blue color. The color is due to color of conidia, not to color of substratum alone, as can be observed under the microscope.

Hab. On rotted tubers of *Solanum tuberosum* and on other plants, in the United States and in Europe. The organism was isolated by the writer from specimens received from various States.

Measurements of conidia on different media are as follows:

On potato tuber plug, culture seventy days old; conidia from pseudopionnotes:

Conidia: 0–septate, rare
1–septate, 3 per cent
2–septate, rare
3–septate, 60 per cent, 46 x 5.3 (38–51 x 5.2–5.7)μ
4–septate, 30 per cent, 50 x 5.4 (43–54 x 5.2–5.9)μ
5–septate, 7 per cent, 52 x 5.6 (45–54 x 5.2–5.9)μ

On slightly acidified hard potato agar, culture eleven days old; conidia from thin pseudopionnotes:

Conidia: 0–septate, 2 per cent, 11 x 4μ
1–septate, 2 per cent, 20 x 4.5μ
2–septate, rare
3–septate, 23 per cent, 43.5 x 5.2 (33–51 x 4.6–5.3)μ
4–septate, 68 per cent, 49 x 5.6 (42–65 x 4.6–6.7)μ
5–septate, 5 per cent, 60 x 5.85 (56–63 x 5.6–6.45)μ

On red raspberry cane plug, culture eighty-two days old; conidia from a sporodochium:

Conidia: 1– and 2–septate, rare
3–septate, 57 per cent, 44 x 5.1 (29–50 x 4.3–5.9)μ
4–septate, 43 per cent, 51 x 5.3 (40–54 x 4.7–5.9)μ
5–septate, rare, 54 x 5.4μ (only one measured)

On potato tuber plug, culture sixty-four days old; conidia from thick pseudopionnotes:

Conidia: 0–septate, rare, about 9 x 3.5μ
3–septate, 55 per cent, 43 x 4.9 (28–50 x 4.7–5.1)μ
4–septate, 45 per cent, 48 x 4.9 (43–55 x 4.7–5.7)μ
5–septate, very rare

On hard lima-bean agar, culture sixty-eight days old; conidia from a small sporodochium:

Conidia: 0– to 2–septate, very rare
3–septate, 48 per cent, 42 x 5.2 (30–51 x 4.8–5.9)μ
4–septate, 50 per cent, 48 x 5.3 (41–53 x 4.8–5.9)μ
5–septate, 2 per cent, 51 x 5.5 (43–56 x 5–5.9)μ

On same medium and of same age as above, conidia from a medium large (about 2 millimeters in diameter), short, column-like sporodochium:

Conidia: 0– to 2–septate, very rare
3–septate, 49 per cent, 45 x 5.2 (36–49 x 4.5–5.6)μ
4–septate, 51 per cent, 50 x 5.2 (38–56 x 4.8–5.6)μ
5–septate, very rare

Average of the above measurements:

Conidia: 0–septate, rare, 11 x 4μ
1–septate, 1 per cent, 20 x 4.5μ
2–septate, very rare
3–septate, 53 per cent, 43.9 x 5.15μ
4–septate, 43 per cent, 49.3 x 5.3μ
5–septate, 3 per cent, 54.3 x 5.57μ

The average sizes given by Appel and Wollenweber for the same fungus are:

Conidia: 3–septate, about 44 per cent, 49 x 5.25μ
4–septate, about 51.5 per cent, 55 x 5.5μ
5–septate, about 4.5 per cent, 56.5 x 5.5μ

54. *Fusarium Martii* Ap. et Wr. var. **viride** n. var. (Fig. 44, A to I; Pl. VI, fig. 5)

Differs from *F. Martii* by having macroconidia somewhat narrower, and usually by a paler color of conidia and substratum; dark blue color of conidial masses not observed. Typical color of conidia in mass, on potato agar rich in glucose, pale smoke-gray, and of substratum pale drab-gray.

Hab. In discolored fibrovascular bundles of *Solanum tuberosum*, in stems and tubers, at Atlanta and Castile, New York.

Measurements of conidia on various media are as follows:

On potato tuber plug, culture seventy-one days old; conidia from pseudopionnotes:

Conidia: 0–septate, 4 per cent
1–septate, 22 per cent
2–septate, 10 per cent
3–septate, 60 per cent, 39 x 5 (33–43 x 4.6–5.2)μ
4–septate, 4 per cent

On slightly acidified hard potato agar, culture eight days old; conidia from pseudopionnotes:

Conidia: 0–septate, rare, 9 x 4μ
1–septate, rare, 17 x 5μ
2–septate, rare
3–septate, 41 per cent, about 46 x 5 (42–51 x 4.4–5.25)μ
4–septate, 58 per cent, 54.4 x 5.25 (45–68 x 4.8–5.6)μ
5–septate, 1 per cent, 58.5 x 5.7 (50–62 x 5–6)μ

On red raspberry cane plug, culture eighty-six days old; conidia from a sporodochium:

Conidia: 3–septate, 50 per cent, 45 x 5.2 (36–53 x 5–5.4)μ
4–septate, 50 per cent, 54 x 5.4 (42–61 x 5.2–5.9)μ

On hard lima-bean agar, culture twenty-two days old; conidia from pseudopionnotes:

Conidia: 3–septate, 90 per cent, 46.1 x 5 (40–49 x 4.7–5.3)μ
4–septate, 9 per cent
5–septate, 1 per cent

On potato tuber plug, culture sixty-four days old; conidia from thick pseudopionnotes:

Conidia: 3–septate, 55 per cent, 45 x 4.9 (40–49 x 4.8–5.3)μ
4–septate, 45 per cent, 49 x 5.3 (45–53 x 5–5.6)μ

On hard lima-bean agar, culture seventy-two days old; conidia from a columnar sporodochial mass:

Conidia: 3–septate, 73 per cent, 45 x 5.1 (40–49 x 4.7–5.3)μ
4–septate, 27 per cent, 50 x 5.2 (47–51 x 5–5.6)μ

Average of the above measurements:
Conidia: 0–septate, 0.5 per cent, 9 x 4μ
1–septate, 3 per cent, 17 x 5μ
2–septate, 1 per cent
3–septate, 63 per cent, 44.4 x 5.03μ
4–septate, 32 per cent, 51.9 x 5.27μ
5–septate, 0.5 per cent, 58.5 x 5.7μ

55. ***Fusarium Martii*** **Ap. et Wr. var. minus n. var.** (Fig. 44, J to L; Pl. I, figs. 3 and 4; Pl. VI, fig. 6)

Differs from *F. Martii* and *F. Martii* var. *viride* by having smaller, 3-septate, conidia, 36.7 x 4.8 (30–44 x 4.55–5.1)μ, usually prominent development of plectenchymic, wartlike stromata, and fewer and larger sporodochia (Pl. VI, fig. 6).

Color of substratum, on potato agar rich in glucose, from light gray to drab and dark olive-buff, with a fuscous-colored spot at the point of inoculation (Pl. I, figs. 3 and 4).

Hab. On rotted tubers of *Solanum tuberosum*, evidently following *Phytophthora infestans*, Dutchess County, New York.

Measurements of conidia on different media are as follows:

On potato tuber plug, culture seventy-one days old:
(1) Conidia from a sporodochium
Conidia: 0–septate, 8 per cent
1–septate, 13 per cent
2–septate, 29 per cent
3–septate, 50 per cent, 30 x 4.6 (26–33 x 3.6–4.8)μ
(2) Conidia from pseudopionnotes
Conidia: 1–septate, 9 per cent
2–septate, 37 per cent
3–septate, 54 per cent, 30 x 4.55 (27–34 x 3.9–4.8)μ
(3) Conidia from oldest part of pseudopionnotes
Conidia: 3–septate, 100 per cent, 37 x 4.7 (27–43 x 4.2–5)μ

On slightly acidified hard potato agar, culture eleven days old; conidia from pseudopionnotes:
Conidia: 3–septate, 67 per cent, 43.75 x 4.6 (24–52 x 3.5–5.3)μ
4–septate, 28 per cent, 48.65 x 5 (43–53 x 4.3–5.3)μ
5–septate, 5 per cent, 52.85 x 5 (50–57 x 4.3–5.3)μ

On red raspberry cane plug, culture eighty-five days old; conidia from a sporodochium:

Conidia: 0–septate, rare
1–septate, rare
2–septate, rare
3–septate, 80 per cent, 38 x 5.1 (28–48 x 4.1–5.3)μ
4–septate, 20 per cent, 47 x 5.2 (42–52 x 4.9–5.5)μ
5–septate, rare, 47 x 5.2μ (only one measured)

On hard lima-bean agar with 2 per cent glucose, culture twenty-two days old:

Conidia: 3–septate, 88 per cent, 41.4 x 4.7 (36–47 x 4.1–5.3)μ
4–septate, 10 per cent
5–septate, 2 per cent

On potato tuber plug, culture sixty-four days old; conidia from pseudopionnotes:

Conidia: 0–septate, very rare
3–septate, 86 per cent, 40 x 4.8 (33–49 x 4.1–5.2)μ
4–septate, 14 per cent, 48 x 4.9 (38–56 x 4.7–5.7)μ

On hard lima-bean agar with 2 per cent glucose, culture sixty-eight days old; conidia from a columnar mass:

Conidia: 0– to 2–septate, very rare
3–septate, 93 per cent, 40 x 5.1 (30–45 x 4.7–5.4)μ
4–septate, 7 per cent, 44 x 5.1 (36–48 x 4.7–5.4)μ
5–septate, very rare, 47 x 5.3μ (only one measured)

On same medium, culture also same age; conidia from pseudopionnotes:

Conidia: 0– to 2–septate, very rare
3–septate, 98 per cent, 41 x 5 (33–42 x 4.7–5.3)μ
4–septate, 2 per cent, 44 x 5.1 (40–50 x 4.8–5.3)μ

Average of the above measurements:

Conidia: 0–septate, 11 per cent
1–septate, 2 per cent
2–septate, 6.6 per cent
3–septate, 71.6 per cent, 36.7 x 4.8μ
4–septate, 8.1 per cent, 46.2 x 5.06μ
5–septate, 0.7 per cent, 50 x 5.17μ

56. *Fusarium Solani* (Mart. p. par.) Ap. et Wr. (Fig. 1, X_1 and Y_1; Fig. 45, A to G; Pl. I, fig. 1; Pl. VI, fig. 7)

Appel, O., and Wollenweber, H. W., Arb. K. biol. Anst. Land- u. Forstw. 8:64–78; Pl. I, figs. 1 to 30; Pl. III, fig. 1; text fig. 4. 1910.

Microconidia always present, at least on aërial mycelium, same size and shape as those of *F. Martii*. Macroconidia typically somewhat broader

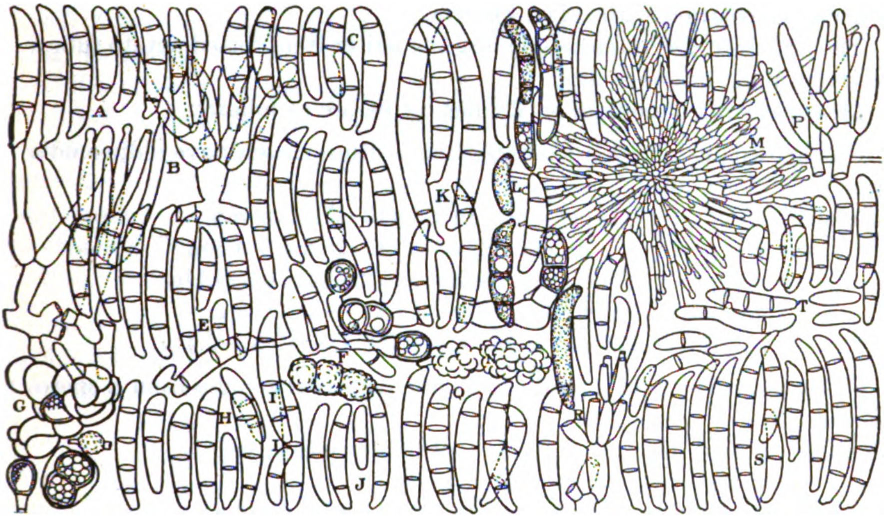

FIG. 45.— A-G, *Fusarium Solani*. A, *Conidia from plectenchymic sporodochia from 66-days-old culture on potato tuber plugs;* B, *conidiophores,* C, *conidia, from aërial mycelium from 12-days-old culture on hard lima-bean agar;* D, *pseudopionnotal conidia from 11-days-old culture on slightly acidified hard potato agar;* E, *conidia from sporodochium from 87-days-old culture on red raspberry cane plug;* F, *terminal, 1- to 3-septate, chlamydospores produced by hyphæ and conidia, the latter anastomosed, from 173-days-old culture on corn agar;* G, *terminal and intercalary, clustered, chlamydospores from 70-days-old culture on potato tuber plug*

H-J, *Fusarium Solani var. cyanum.* H, *Sporodochial conidia from 87-days-old culture on red raspberry cane plug;* I, *pseudopionnotal conidia from 15-days-old culture on slightly acidified hard potato agar;* J, *aërial conidia from 87-days-old culture on red raspberry cane plug*

K-T, *Fusarium Solani var. suffuscum.* K, *Pseudopionnotal conidia from 7-days-old colony in petri dish on hard potato agar (the middle spore above is typical for the culture);* L, *sporodochial conidia from 47-days-old culture on rye straw (many conidia have coarsely granulated protoplasm and oil globules);* M, *compound conidiophore in form of dense tuft (looking from above, magnification 250 times), from 47-days-old culture on potato stem plug;* N, *chlamydospores,* O, *sporodochial conidia, from 70-days-old culture on potato tuber plug;* P, *typical ends of conidiophores from 47-days-old culture on potato stem plug;* Q, *sporodochial conidia from 87-days-old culture on red raspberry cane plug;* R, *sporodochial conidia and conidiophore from 13-days-old culture on potato tuber plug;* S, *sporodochial conidia from 16-days-old culture on slightly acidified hard potato agar;* T, *sporodochial conidia from 47-days-old culture on potato stem plug*

in upper half of their length, with from rounded to slightly constricted apex, not at all or slightly pedicellate, typically 3–septate, 29.75 x 5.5 (27–34.7 x 5.4–5.8)μ, sometimes 4–septate, rarely 5–septate; aërial mycelium from poorly to well developed, from white to olive-buff; substratum, on potato agar rich in glucose, olive–buff with a green–blue tinge (Pl. I, fig, 1, and Pl. VI, fig. 7).

Hab. On *Solanum tuberosum* and other substrata, in Europe and America; often in association with other Fusaria.

The organism was often isolated by the writer from rotted potato tubers received from various States.

Measurements of conidia on various media are as follows:

On slightly acidified hard potato agar, culture eleven days old; conidia from pseudopionnotes:

Conidia: 1–septate, 0.5 per cent, 14 x 4 (13–17 x 3.5–5.8)μ
2–septate, 1 per cent, 22 x 4.5 (17–28 x 4.2–4.8)μ
3–septate, 93 per cent, 34.7 x 5.4 (22–42 x 4.3–6.1)μ
4–septate, 5 per cent, 38 x 5.8 (30–43 x 5–6.4)μ
5–septate, 0.5 per cent, 44.3 x 5.8 (38–47 x 5–6.4)μ

On potato tuber plug, culture sixty-five days old; conidia from a sporodochium:

Conidia: 0–septate, rare, 8.7 x 4μ (only a few measured)
1–septate, 2 per cent, 20 x 4.6μ
2–septate, 4 per cent, 23 x 4.7 (18–25 x 4.4–5.4)μ
3–septate, 93 per cent, 28 x 5.8 (22–35 x 4.8–6.1)μ
4–septate, 1 per cent, 33–5.9 (28–38 x 5.4–6.1)μ

On hard lima-bean agar, culture twelve days old:

(1) Conidia from aërial mycelium

Conidia: 0–septate, 20 per cent
1–septate, 40 per cent
2–septate, 19 per cent
3–septate, 21 per cent, 27 x 5.4 (24–37 x 4.7–6)μ

(2) Conidia from a sporodochium

Conidia: 0–septate, 1 per cent
1–septate, 1 per cent
2–septate, 1 per cent
3–septate (97 to 100 per cent), 29.3 x 5.4 (24–35 x 4.8–5.9)μ

Average of the above measurements:
Conidia: 0–septate, 5 per cent, 8.7 x 4μ
1–septate, 11 per cent, 17 x 4.3μ
2–septate, 6 per cent, 22.5 x 4.6μ
3–septate, 76.5 per cent, 29.75 x 5.5μ
4–septate, 1.5 per cent, 35.5 x 5.85μ
5–septate, rare, 44.3 x 5.8μ

57. *Fusarium Solani* (Mart. p. par.) Ap. et Wr. var. **cyanum** n. var. (Fig. 45, H to J)

Differs from *F. Solani* mainly by having macroconidia typically more rounded at apex and base, by fewer 4–septate and absence of 5–septate conidia, and by frequent occurrence of bluish plectenchyma (on hard bean agar and potato tuber plugs); sometimes distinct blue color in conidia also observable; size for the same septation type of conidia almost the same as that of *F. Solani.*

Hab. Same as for *F. Solani,* but much less common.

On potato tuber plug, culture sixty-eight days old; conidia from a sporodochium:
Conidia: 0–septate, 28 per cent
1–septate, 22 per cent
2–septate, 35 per cent
3–septate, 15 per cent, 28 x 5.2 (24–31 x 4.8–5.7)μ

On slightly acidified hard potato agar, culture fifteen days old; conidia from pseudopionnotes:
Conidia: 0–septate, 14 per cent, 12 x 3.7 (8.7–14 x 2.5–5)μ
1–septate, 22 per cent, 24.5 x 4.5 (15–30 x 3.5–5.3)μ
2–septate, 19 per cent, 29 x 5 (24–32 x 4.8–5.3)μ
3–septate, 45 per cent, 33 x 5.7 (31–35 x 5–6)μ

On red raspberry cane plug, culture eighty-seven days old; conidia from a sporodochium:
Conidia: 0–septate, few
1–septate, 3 per cent
2–septate, 5 per cent, 25 x 5.5 (19–27 x 4.7–5.8)μ
3–septate, 90 per cent, 30 x 5.7 (28–35 x 5.2–5.9)μ
4–septate, 2 per cent, 35 x 5.5 (33–37 x 5.2–5.7)μ

On potato tuber plug, culture sixty-five days old; conidia from a sporodochium:

Conidia: 0–septate, few
1–septate, 12 per cent, about 22 x 5μ (only one measured)
2–septate, 16 per cent, about 27 x 5.3μ (only one measured)
3–septate, 72 per cent, 29 x 5.6 (24–35 x 4.8–5.9)μ

On corn agar, culture one hundred and seventy-five days old; conidia only few, chlamydospores numerous, terminal and intercalary:

Chlamydospores: 0–septate, in mycelium, 11.3 x 9.3 (8.5–16 x 7.5–11)μ
1–septate, in mycelium, 16.3 x 9.9 (14–20 x 8–14)μ

On hard lima-bean agar, culture twelve days old; conidia from pseudopionnotes:

Conidia: 0–septate, 4 per cent
1–septate, 15 per cent
2–septate, 16 per cent
(percentage may vary considerably from somewhat greater than figures given here to nearly zero)
3–septate, 65 per cent, 33 x 5.2 (27–37 x 4.7–5.6)μ

Average of the above measurements:

Conidia: 0–septate, 9 per cent, 12 x 3.7μ
1–septate, 15 per cent, 23 x 4.75μ
2–septate, 18 per cent, 27 x 5.3μ
3–septate, 57.5 per cent, 30.5 x 5.5μ
4–septate, 0.5 per cent, 35 x 5.5μ

58. *Fusarium Solani* (Mart. p. par.) Ap. et Wr. var. **suffuscum** n. var. (Fig. 45, K to T)

Differs from *F. Solani* and *F. Solani* var. *cyanum* mainly by typically well-developed, uniform, fine, aërial mycelium, with mass of chlamydospores at maturity which gives it a pale brownish tint; by sparse conidial production on aërial mycelium; and by the fact that sporodochia are usually few and distant from one another.

Hab. On rotted tubers of *Solanum tuberosum*, Wisconsin.

The average size and occurrence of septation type of conidia on various media are as follows:

Conidia: 0–septate, 5.5 per cent, 10.7 x 3.15μ
1–septate, 13.5 per cent, 20 x 4.5μ
2–septate, 17 per cent, 25 x 4.5μ
3–septate, 60.5 per cent, 30 x 5.41μ
4–septate, 3.5 per cent, 34.5 x 5.5μ
5–septate, rare, 42.25 x 5.85μ

59. **Fusarium striatum** n. sp. (Figs. 1c_2 and 46; Pl. I, fig. 2)

Microconidia, at least on aërial mycelium, always present. Macroconidia of shape and septation intermediate between *F. Martii* and *F. Solani*, mostly 3–septate, 34.7 x 4.6 (31–36 x 4.4–5)μ, from colorless to

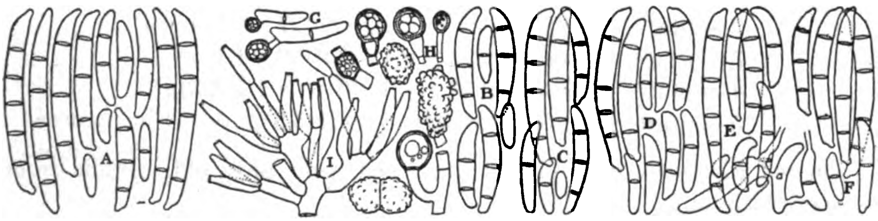

FIG. 46.—*Fusarium striatum.* A, *Pseudopionnotal conidia from 17-days-old culture on slightly acidified hard potato agar;* B, *pseudopionnotal conidia from 58-days-old culture on oats;* C, *conidia from small sporodochium from 32-days-old culture on hard lima-bean agar;* D, *sporodochial conidia from 86-days-old culture on red raspberry cane plug;* E, *pseudopionnotal conidia from 13-days-old potato tuber plug (some of them anastomosing);* F, *pseudopionnotal conidia from 12-days-old culture on hard lima-bean agar;* G, *terminal chlamydospores produced by conidia from 64-days-old culture on hard lima-bean agar with 2 per cent glucose;* H, *chlamydospores from 32-days-old culture on hard lima-bean agar;* I, *compound conidiophore from 34-days-old culture on hard lima-bean agar*

yellowish glaucous and pale turquoise green, in numerous minute sporodochia; sporodochia often converging into a pseudopionnotes; aërial mycelium short (rarely up to 3 millimeters high), typically (on various agars) fine, uniformly from loose to very loose, downy in appearance, from white to grayish white; substratum, on agars rich in glucose, from pale glaucous green to tawny olive and sepia.

Hab. On tubers of *Solanum tuberosum*, Colorado.

Latin description.—Microconidiis—saltem in aerio mycelio—semper praesentibus; macroconidiis forma et septatione inter F. Martii et F.

Solani mediis, plerumque 3–septatis, 34.7 x 4.6 (31–36 x 4.4–5)μ, ex hyalino luteolo-glaucis vel pallide "turquoise green" (R), multis minutis sporodochiis; sporodochiis saepe in pseudopionnotem vergentibus; aerio mycelio brevi (usque ad 3 mm. alt.) typice (in agaribus variis) subtili, aequabiliter laxo vel laxissimo, pubescenti viso, ex albo caesio-albo; substrato—in agaribus perglucosis—ex pallide glauco-viridi "tawny-olive" (R) et "sepia" (R).

Hab. In tuberibus Solani tuberosi, Colorado, Amer. bor.

Measurements of conidia on different media are as follows:

On slightly acidified hard potato agar, culture seventeen days old; conidia from pseudopionnotes:

Conidia: 0–septate, 6 per cent, 10.6 x 3.15 (8.5–12.5 x 2.5–3.5)μ
1–septate, 10 per cent, 19.5 x 3.9 (14–21 x 3–4.4)μ
2–septate, 4 per cent, 24.15 x 4.2 (21–27 x 3.5–4.7)μ
3–septate, 64 per cent, 36.4 x 4.4 (26–50 x 4–5)μ
4–septate, 16 per cent, 47 x 4.5 (40–56 x 4.3–5.3)μ
5–septate, rare, 50 x 4.8 (47–56 x 4.3–5.3)μ

On red raspberry cane plug, culture eighty-six days old; conidia from a sporodochium:

Conidia: 0–septate, 3 per cent
1–septate, 7 per cent, 19 x 3.5 (12–23 x 3–4.1)μ
2–septate, 2 per cent
3–septate, 88 per cent, 41.6 x 5 (24–44 x 4–5.7)μ
4–septate, very rare, 43 x 5 (only one measured)

On hard lima-bean agar with 2 per cent glucose, culture sixty-four days old; conidia from pseudopionnotes:

Conidia: 0–septate, 10 per cent
1–septate, 22 per cent, 22 x 4.1 (16-30 x 3.5–4.7)μ
2–septate, 10 per cent
3–septate, 58 per cent, 31 x 4.6 (22–37 x 4.2–5)μ

On rye grain, culture sixty-four days old; conidia from a sporodochium:

Conidia: 0–septate, 39 per cent
1–septate, 28 per cent, 20 x 3.9 (14–23 x 3.5–4.4)μ
2–septate, 5 per cent
3–septate, 28 per cent, 31 x 4.6 (24–36 x 4.3–5)μ

On hard lima-bean agar, culture twelve days old:

(1) Conidia from a sporodochium
  0–septate, 13 per cent
  1–septate, 30 per cent
  2–septate, 7 per cent
  3–septate, 50 per cent, 33 x 4.4 (24–44 x 3.6–4.7)μ
  4–septate, very few

(2) Chlamydospores, terminal and intercalary, mostly 0–septate, 9 x 7.5 (7–11 x 6–9)μ

On same medium as above, culture thirty-two days old; conidia from a sporodochium:

Conidia: 0–septate, 1 per cent, 9 x 3.6μ (only a few measured)
  1–septate, 20 per cent, 20 x 3.9 (14–25 x 3.5–4.1)μ
  2–septate, 5 per cent, 25 x 4.2 (23–30 x 4–4.4)μ
  3–septate, 73 per cent, 35 x 4.6 (28–37 x 4–4.7)μ
  4–septate, 1 per cent, 41 x 4.7μ (only a few measured)

Average of the above measurements:

Conidia: 0–septate, 12 per cent, 10 x 3.4μ
  1–septate, 19.5 per cent, 20 x 3.9μ
  2–septate, 5.5 per cent, 24.5 x 4.2μ
  3–septate, 60 per cent, 34.7 x 4.6μ
  4–septate, 3 per cent, 43.7 x 4.7μ
  5–septate, very rare, 50 x 4.8μ

60. *Fusarium radicicola*[57] Wr. (Fig. 47; Pl. VI, fig. 8)

Wollenweber, H. W., Journ. Agr. Research 2:257-258, Pl. XVI, fig. K, 1914.

Microconidia nearly straight near base, slightly curved in upper third of their length, with from somewhat rounded to distinctly constricted apex, slightly pedicellate, mostly 3–septate, 35.2 x 4.7 (31–40 x 4.6–5)μ; 0– and 1–septate, microconidia very common, 0–septate measuring 8 x 3μ; chlamydospores common, terminal and intercalary, mostly 0– and 1–septate, 0–septate averaging 9–10 x 8.7–8.8μ; pseudopionnotes typically

[57] In an article which appeared after this work was ready for press, Dr. Wollenweber (1914) describes a new species of Fusarium (*F. radicicola*) with which this organism appears identical. No cultural comparisons have been possible, but the type of tuber rot and type of conidia are alike, and in certain instances material for study has come from the same region. Possibly any differences may be accounted for in the difference in strains studied.

absent; plectenchymic sporodochia often present; aërial mycelium well developed; color of conidia from white to olive, of substratum from pale yellowish to olive (on agar rich in glucose and on potato tuber plug).

Hab. On rotted tubers of *Solanum tuberosum*, in Oregon, Idaho, and California.

F. radicicola differs from *F. Martii* and *F. Martii* var. *viride* by shorter macroconidia; from *F. Martii* var. *minus* by absence of prominent plectenchymic sporodochia; and from *F. striatum* by well-developed aërial mycelium and by typical absence of pseudopionnotes.

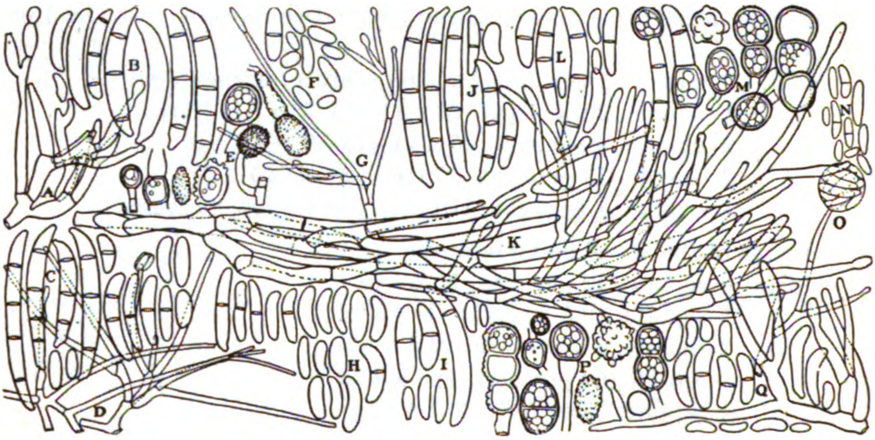

Fig. 47.—*Fusarium radicicola.* A, *Conidiophore,* B, *sporodochial conidia, from 67-days-old culture on potato stem plug;* C, *aërial and pseudopionnotal conidia from 12-days-old culture on hard lima-bean agar;* D, *conidiophore (magnification 250 times) from 48-days-old culture on rye straw;* E, *chlamydospores,* F, *aërial conidia,* G, *conidiophore (magnified 250 times), from 73-days-old culture on red raspberry cane plug;* H, *conidia from the surface of original stem-end rotted potato tuber;* I, *conidia from 48-days-old culture on rye straw;* J, *conidia from pseudopionnotes in 7-days-old colony in petri dish on hard potato agar;* K, *conidiophore from the surface of original stem-end rotted potato tuber;* L, *aërial conidia close to substratum from 64-days-old culture on hard lima-bean agar;* M, *chlamydospores produced in mycelium and conidia from 173-days-old culture on corn agar;* N, *conidia,* O, *spore ball, both magnified 250 times, from 3-days-old hanging drop culture in potato decoction in van Tieghem cell;* P, *chlamydospores from 82-days-old culture on potato tuber plug;* Q, *conidia and conidiophores from 26-days-old culture on oats*

Production of macroconidia in sporodochia was observed to be abundant only under certain conditions (not well determined as yet), but usually microconidia alone are the dominant type. The Oregon specimens, from which cultures of the fungus were first obtained, showed a

dark, depressed area of dry rot at the stem end of the tubers, with cream-white, dense tufts of conidiophores, up to 1 centimeter high and powdered with conidia. (For microscopic characters see figure 47.) Pure cultures of this organism were obtained both from the aërial conidia and from plantings of the rotted tissues of the tubers.

The organisms in general differ much from *F. striatum*, but in certain cultures (in sporodochia-producing stage on whole steamed potato tubers) resemble it very closely.

Measurements of conidia on different media are as follows:

On potato tuber plug, culture eighty-two days old:

(1) Conidia from aërial mycelium

Conidia: 0–septate, 95 per cent, 8 x 3 (6–15 x 2.1–4)μ
1–septate, 5 per cent, 15 x 4 (13–21 x 3.4–4.4)μ
3–septate, rare

(2) Chlamydospores, intercalary and terminal, unicellular and in chains
0–septate, 9.8 x 8.7 (5.2–16 x 5.2–12)μ

On hard lima-bean agar with 2 per cent glucose, culture sixty-four days old:

(1) Conidia from aërial mycelium close to substratum

Conidia: 0–septate, 80 per cent
1–septate, 17 per cent } (size same as above)
2–septate, 2 per cent
3–septate, 1 per cent, 33 x 4.8 (22–41 x 4.3–5.2)μ
4–septate, rare, 45 x 4.8 (only a few measured)

(2) Chlamydospores
0–septate, 9.5 x 8.8 (6.1–12 x 5.2–11)μ
1–septate, 18 x 10 (16–22 x 5–12)μ

On hard lima-bean agar, culture twelve days old:

(1) Conidia from aërial mycelium

Conidia: 0–septate, 60 per cent
1–septate, 30 per cent
2–septate, 1 per cent
3–septate, 6 per cent, 37 x 4.5 (28–48 x 4–5.3)μ
4–septate, 3 per cent, 43.6 x 5 (40–49 x 4.3–5.2)μ
5–septate, rare, size about that of 4–septate

(2) Chlamydospores, mostly 0–septate, 9 x 8.7μ

On whole steamed potato tuber, culture sixty days old; conidia from a sporodochium:

Conidia: 0–septate, 11 per cent
1–septate, 21 per cent
2–septate, 8 per cent
3–septate, 60 per cent, 31 x 4.8 (29–38 x 4.2–5.5)μ
4–septate, very rare

On oat grain, culture fifty-seven days old; conidia from a sporodochium, septation as above:

Conidia: 3–septate, 35.2 x 4.7 (25–42.5 x 4.2–5)μ
4–septate, 43 x 5μ (only one measured)

On potato stem plug, culture seventy days old; conidia from a sporodochium, septation approximately that given above:

Conidia: 3–septate, 35.2 x 5 (24.5–38 x 3.7–5.5)μ
4–septate, 41.6 x 5.8μ (only one measured)

On hard potato agar, culture ten days old; conidia from aërial mycelium close to substratum:

Conidia: 0–septate, 30 per cent
1–septate, 10 per cent
2–septate, 5 per cent
3–septate, 50 per cent, 40 x 4.6 (32–46 x 4.3–4.9)μ
4–septate, 5 per cent, 47 x 4.8 (45–49 x 4.5–5)μ

Average of the above measurements:

Conidia: 0–septate, 56 per cent (from 11 to 95 per cent), 8 x 3μ
1–septate, 16 per cent (from 5 to 30 per cent), 15 x 4μ
2–septate, 3 per cent (from 0 to 8 per cent)
3–septate, 23 per cent (from 0 to 60 per cent), 35.2 x 4.73μ
4–septate, 2 per cent (from 0 to 5 per cent), 43.9 x 5.1μ
5–septate, very rare, size about that of 4–septate

61. *Fusarium coeruleum* (Lib.) Sacc. (Figs. 1B$_2$ and 48; Pl. I, figs. 5 and 6; Pl. VI, fig. 4)

Syn. *Fusarium violaceum* Fuckel. 1869.
Selenosporium coeruleum Libert, in herbarium.

Cf. Saccardo, Syll. Fung. 4:705. 1886. Appel, O., and Wollenweber, H. W., Arb. K. biol. Anst. Land- u. Forstw. 8:84–91, Pl. III fig. 6,

text fig. 6. 1910. Wollenweber, H. W., Phytopath. 3:31, 44, 45, Fig. 1c. 1913.

Microconidia of larger size than those of other species of section Martiella, 0–septate, about 16 x 4.7μ. Macroconidia, for the largest part, of an even diameter or somewhat broader toward the base, only slightly curved near, and more or less rounded at, the apex, never apically constricted, mostly apedicellate or with ventrally depressed basal cell, mostly 3–septate, 33.3 x 5 (30–36 x 4.5–5.4)μ; aërial mycelium usually medium

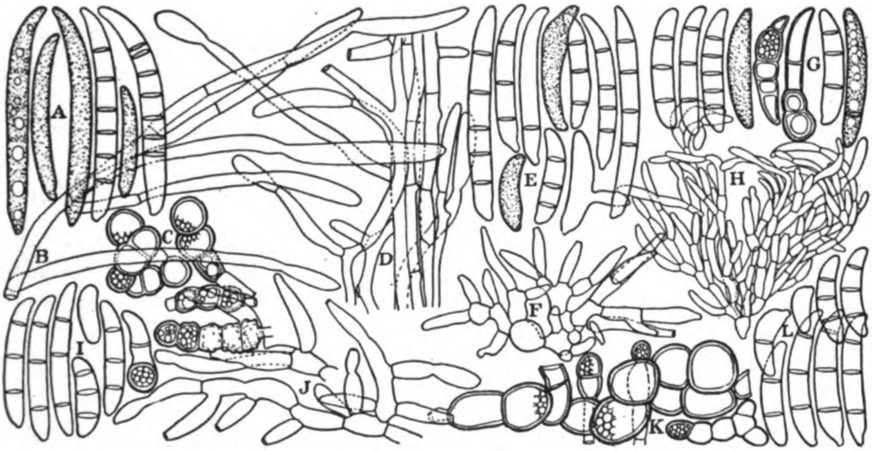

FIG. 48.—*Fusarium coeruleum.* A, *Pseudopionnotal conidia*, B, *conidiophore, from 8-days-old colony in petri dish on hard potato agar;* C, *chlamydospores*, D, *coremium-like form of mycelial growth with conidiophores*, E, *pseudopionnotal conidia, from 35-days-old culture on potato tuber plug;* F, *conidiophore from 62-days-old culture on rye straw;* G, *conidia (some with chlamydospores)*, H, *conidiophore (magnified 250 times), from 54-days-old culture on rye straw;* I, *conidia from small sporodochium*, J, *conidiophore, from 79-days-old culture on red raspberry cane plug;* K, *chlamydospores*, L, *pseudopionnotal conidia, from 22-days-old culture on hard potato agar.* A, B, F, G, *and* H *are from strains isolated from rotted potato tubers received from American sources, the remainder are from the culture received from Dr. Wollenweber*

well developed, feltlike in age, of from white, bluish white, and olive-buff to dusky slate violet, on potato agar rich in glucose, and to slate purple on corn meal agar; substratum, on potato agar rich in glucose, from deep hyssop violet to indian lake, ocher-red, and, in older cultures, violet-carmine; color of conidia from orchraceous orange, on strong acid agars, to pale buff and mouse gray, or often blue, on neutral media.

Hab. On rotted tubers of *Solanum tuberosum*, common in Europe and

America. Cause of most of fusarial rot on potatoes in storage, often occurring in association with other Fusaria.

The organism was repeatedly isolated by the writer from diseased tubers, and every strain isolated proved capable of producing more or less dark-colored dry rot on tubers. It may be mentioned here that a white rot of tubers can be produced by certain species of Fusarium of the Elegans section, such as *F. lutulatum*. A rot distinctly striate in appearance was often produced by inoculation with *F. striatum*; a brownish rot of tubers is caused by *F. trichothecioides*; and a more or less pinkish rot with large cavities, more or less covered with red masses of macroconidia, is produced by *F. subulatum* and *F. subulatum* var. *brevius*.

Of all these, *F. coeruleum* is the commonest and most vigorous wound parasite of potato tubers; the next, perhaps, is *F. subulatum* and its variety.

Measurements of conidia of a few strains of the species on different media are as follows:

On slightly acidified hard potato agar, culture twenty-two days old; conidia from pseudopionnotes, strain 66:

Conidia: 0–septate, 5 per cent, 16 x 4.7 (6–28 x 4.3–5.5)μ
1–septate, 9 per cent, 21 x 4.7 (17–27 x 4.4–5.3)μ
2–septate, 10 per cent, 25 x 5.3 (18–32 x 4.6–5.9)μ
3–septate, 75 per cent, 30 x 5.4 (20–40 x 4.7–6.1)μ
4–septate, 1 per cent, 36 x 5.5 (33–40 x 5.2–6.1)μ

On red raspberry cane plug, culture seventy-nine days old; conidia from a sporodochium, strain 66; 3–septate, up to 100 per cent, 33 x 5.4 (22–40 x 4.8–6)μ; average septation being

Conidia: 0–septate, 3 per cent
1–septate, 11 per cent
2–septate, 8 per cent
3–septate, 78 per cent
4–septate, rare

On corn meal agar, culture one hundred and seventy-five days old; strain 53; very few conidia observed; chlamydospores numerous:

Chlamydospores: 0–septate, 8 x 7.5 (5.2–10.5 x 5.2–9)μ
1–septate, 11.7 x 7.7 (9.2–14 x 7–8.5)μ
Also in chains in mycelium, 9 (7.8–11)μ in diameter

On hard potato agar, culture one hundred and fifty days old; conidia from a sporodochium, strain 96:

Conidia: 0–septate, 10 per cent
1–septate, 12 per cent
2–septate, 7 per cent
3–septate, 71 per cent, 36 x 5.1 (33–40 x 4.4–5.5)μ

Chlamydospores: 0–septate, in conidia, average size 8.8 x 8μ

On potato tuber plug, culture eighty-five days old; conidia from a pseudopionnotes, strain 66:

Conidia: 0–septate, 5 per cent
1–septate, 8 per cent
2–septate, 4 per cent
3–septate, 68 per cent, 34.2 x 4.5μ
4–septate, 9 per cent, 42 x 4.6μ (only one measured)
5–septate, 6 per cent, 55 x 5.5μ (only two measured)

On rye straw, culture fifty-four days old; conidia from a sporodochium, strain 96:

Conidia: 0–septate, 2 per cent
1– to 2–septate, 5 per cent
3–septate, 89 per cent, 33.5 x 5.1 (30–37 x 4–6)μ
4–septate, 4 per cent, 33 x 6.1μ (only one measured)

On rye straw, culture fifty days old; conidia from a sporodochium, strain 66:

Conidia: 0– to 2–septate, 5 per cent
3–septate, 88 per cent, 30.5 x 4.9 (28–33 x 4.5–5.3)μ (only three measured)
4–septate, 7 per cent, 33.2 x 5.1μ (only one measured)

On rye straw, culture forty-three days old; conidia from a sporodochium, strain 53:

Conidia: 0– to 2–septate, 23 per cent
3–septate, 73 per cent, 35 x 5 (25–46.2 x 4.7–5.3)μ
4–septate, 4 per cent, 50 x 5μ (only one measured)

On potato hard agar, culture eight days old; strain 190:

Conidia: 0– to 2–septate, 2 per cent
3–septate, 80 per cent
4– and 5–septate, 10 per cent
6– and 7–septate, 8 per cent, 58 x 5.6 (57–60 x 5.2–6)μ

The greatest septation observed was in a culture fifteen days old on oat grains. This was a 9–septate conidium measuring 39 x 5.2μ.

Average of the above measurements:

Conidia: 0–septate, about 4 per cent, 16 x 4.7μ
1–septate, about 6 per cent, 21 x 4.7μ
2–septate, about 5 per cent, 25 x 5.3μ
3–septate, about 78 per cent, 33.3 x 5μ
4–septate, about 4.5 per cent, 39 x 5.26μ
5–septate, about 2 per cent, 55 x 5.5μ
6– and 7–septate, about 0.5 per cent, 58 x 5.6μ

Appel and Wollenweber's measurements for 3–septate conidia average 36 x 5.25 (31–40 x 4.5–5.5)μ

RAMULARIA (UNGER) Fries (Fig. 1, A to C)

Unger, F., Exantheme der Pflanzen, page 169. 1833. Fries, E. M., Summa vegetabilium Scandinaviae, page 493. 1849. Cf. Wollenweber, H. W., Phytopath. 3:33. 1913. Wollenweber, H. W., Phytopath. 3:207–211. 1913.

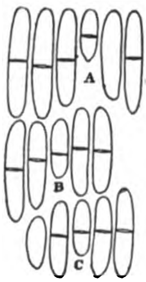

FIG. 49.—*Ramularia eudidyma.* A, *Conidia from aërial mycelium from 55-days-old culture on red raspberry cane plug;* B, *sporodochial conidia from 153-days-old culture on hard lima-bean agar;* C, *conidia from aërial mycelium from 25-days-old culture on slightly acidified hard potato agar*

Differs from Fusarium mainly by nearly cylindrical, apedicellate conidia, with rounded apex; plectenchymic stromata flat to well-developed, wartlike, short column-like structures typically present; conidia borne on conidiophores on aërial mycelium, or on plectenchymic substratum; microconidia (that is, a distinct, abbreviated type of conidia) absent.

1. *Ramularia eudidyma* Wr. (Figs. 1B and 49)

Wollenweber, H. W., Phytopath. 3:221–222, Pl. XXI, fig. C. 1913.

Syn. *Fusisporium didymum* Hartig. 1846.
Fusarium didymum (Hart.) Lindau. 1909.
Fusarium didymum (Hart.) Ap. et Wr. 1910.
Ramularia didyma (Hart.) Wr. 1913.

Conidia nearly cylindrical, with both ends rounded or basal ends sometimes papillate, mostly 1–septate, 23 x 4.87 (21–26 x 4.7–5)μ;[58] 0– to 2–septate conidia

[58] According to Wollenweber's data (1913 c: 234) the average size of 1–septate conidia is 26.4 x 5 (21–29 x 4.25–5.5)μ.

also found, 3-septate very rare; chlamydospores mostly intercalary, 8–11μ in diameter; color of spore mass, from white to yellowish; color of plectenchyma, dense brown.

Hab. On decaying tubers of *Solanum tuberosum* and on roots of *Rubus idæus*, also in soil, Europe.

The organism was not isolated by the writer, but was briefly studied from a culture received through the courtesy of Dr. Wollenweber.

2. *Ramularia Magnusiana* (Sacc.) Lindau (Figs. 1c and 50)

Cf. Wollenweber, H. W., Phytopath. 3:221, 234; Pls. XX, figs. F to H, and XXI, fig. A. 1913.

Conidia of the same type as those of *R. eudidyma*, also mostly 1-septate,

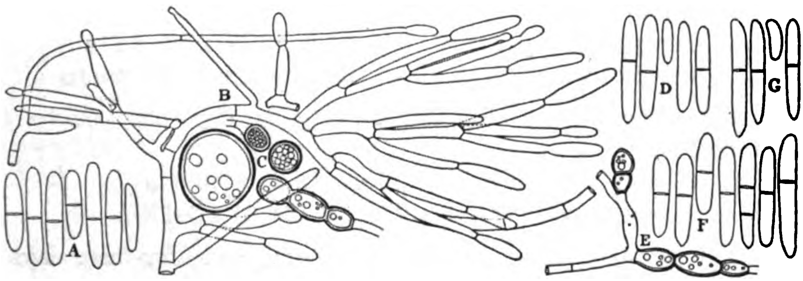

FIG. 50.— *Ramularia Magnusiana.* A, *Conidia from aërial mycelium*, B, *conidiophores, from 11-days-old culture in a petri dish on neutral hard potato agar;* C, *chlamydospores*, D, *sporodochial conidia, from 51-days-old culture on red raspbery cane plug;* E, *chlamydospores from 11-days-old culture in a petri dish on neutral hard potato agar;* F, *conidia from aërial mycelium from 22-days-old culture on slightly acidified hard potato agar;* G, *sporodochial conidia from 153-days-old culture on hard lima-bean agar with 2 per cent glucose*

23.6 x 4.3 (18–27 x 3.5–5)μ;[59] 0- to 3-septate conidia also occurring, not numerous, sometimes catenulate; plectenchyma from olive to coffee brown. Much like *R. candida* (Ehr.) Wr., differing from it by old rose color on rice and by thinner conidia sometimes borne in chains. 0-septate chlamydospores 10 x 11 (7–11 x 9–16)μ; 1-, 2-, and pluri-septate chlamydospores also occurring.

Hab. Common on tubers of *Solanum tuberosum*, also found on the leaves of Trientalis and on the roots of Acer, in Europe and America.

The fungus was isolated several times from rotted potato tubers, New York, the tubers being covered with from a few to many, from dark brown

[59] The size is after Wollenweber (1913 c: 234).

to brick red, plectenchymic bodies, from 2 to 3 millimeters in diameter and from 1 to 4 millimeters high, often bearing characteristic, almost cylindrical, usually 1-septate, conidia.

The strains isolated by the writer differ from those described by Wollenweber, by more reddish color of plectenchyma, by somewhat narrower conidia and larger (?)[60] chlamydospores, and by the absence of persistent conidial chains.

Measurements of conidia of strain 63 on a few different media are as follows:

On slightly acidified hard potato agar, culture twenty-two days old; conidia from aërial mycelium:

Conidia: 0-septate, rare
1-septate, 95 per cent, 26.5 x 4.1 (18–30 x 3.5–4.7)μ
2-septate, 5 per cent, about the same size as 1-septate

On red raspberry cane plug, culture fifty-one days old; conidia from a sporodochium:

Conidia: 0-septate, 50 per cent, 13 x 3 (8–28 x 2.6–4)μ
1-septate, 50 per cent, 27 x 3.9 (24–31 x 3–4.3)μ

On hard lima-bean agar, culture one hundred and fifty-three days old; conidia from a sporodochium:

Conidia: 0-septate, 1 per cent, 10 x 3.4 (7.9–12.3 x 3–3.5)μ
1-septate, 99 per cent, 26 x 3.8 (20–32 x 3.5–4)μ

Average of the above measurements:

Conidia: 0-septate, 17 per cent, 11.5 x 3.9μ
1-septate, 81 per cent, 26.5 x 3.9μ
2-septate, 0 to 5 per cent, same as 1-septate

The average size of conidia according to Wollenweber's measurements is:

Conidia: 0-septate, rare, 14 x 3.8μ
1-septate, 100 per cent, 23.6 x 4.3μ
3-septate, rare, 30 x 5μ

It is possible that strain 63, on a thorough comparative study of it with *R. Magnusiana*, may prove to be a distinct variety; but it is evident that the resemblance between the two in all important characters is close enough to warrant its being placed in the species *R. Magnusiana*.

[60] Wollenweber does not give the size of chlamydospores, but it can be interpreted that it is the same as for *R. candida* (Ehr.) Wr., namely, 5–8μ in diameter. Chlamydospores of the strains described here on corn meal agar in cultures one hundred and seventy-three days old measured 10 x 11 (7–11 x 9–16)μ.

3. **Ramularia Solani** n. sp. (Figs. 1A and 51)

Conidia from nearly cylindrical to slightly curved, with both ends rounded or with basal cell slightly papillate, mostly 1- and 2-septate; 1-septate measuring 29.5 x 6.5 (28–30 x 6.2–6.7)μ, and 2-septate measuring 32 x 6.4 (26–33.7 x 6.3–6.8)μ; plectenchyma flat, usually chocolate brown; aërial mycelium from 2 to 4 millimeters high, from medium dense to medium loose, from chamois to deep olive-buff, on potato agar rich in glucose, often with a chocolate-drab tinge; substratum, on the same medium, in zones of from sepia to tawny olive, and in old cultures to Saccardo's amber; conidia in mass from nearly white to deep olive-buff; no chlamydospores observed.

Hab. On rotted tubers of *Solanum tuberosum*, New York.

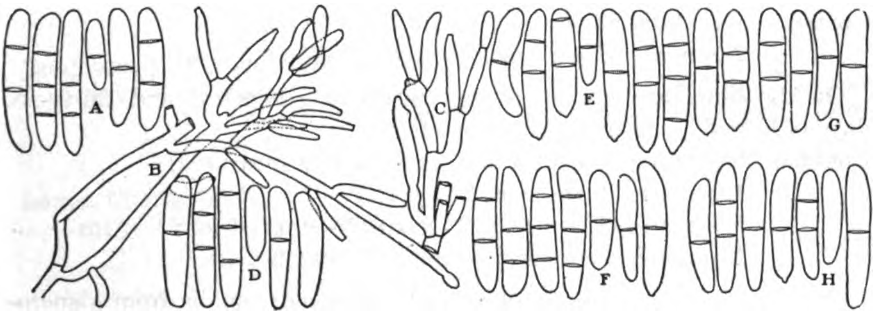

FIG. 51.— *Ramularia Solani.* A, *Sporodochial conidia from 12-days-old culture on oats;* B *and* C, *conidiophores from 34-days-old culture on hard lima-bean agar;* D, *conidia from aërial mycelium from 25-days-old culture on slightly acidified hard potato agar;* E, *conidia from aërial mycelium from 34-days-old culture on hard lima-bean agar;* F, *sporodochial conidia from 8-days-old culture on hard lima-bean agar;* G, *sporodochial conidia from 55-days-old red raspberry cane plug;* H, *sporodochial conidia from 67-days-old flask culture on hard potato agar with 2 per cent glucose*

Latin description.—Conidiis ferme cylindricis vel parum curvatis, utrisque finibus rotundatis vel cella infima parum papillata, plerumque 1–2-septatis; conidiis 1-septatis, 29.5 x 6.5 (28–30 x 6.2–6.7)μ, vel 2-septatis, 32 x 6.4 (26–33.7 x 6.3–6.8)μ; plectenchymate plano, plerumque "chocolate brown" (R); aerio mycelio 2–4 mm. alt., e mediocriter denso mediocriter laxo, e "chamois" (R) "olive-buff" (R), saepe in agare Solani tuberosi perglucoso "chocolate-drab" (R) tincto; substrato, eodem in agare, e "sepia" (R) "tawny olive" (R) in zonis, vel in culturis maturis

"Saccardo's amber" (R); conidiis in totum e ferme albo olivaceo-gilvis; nullis chlamydosporis.

Hab. In tuberibus putridis Solani tuberosi, New York, Amer. bor.

Measurements of conidia on different media are as follows:

On slightly acidified hard potato agar, culture twenty-five days old; conidia from a sporodochium:

Conidia: 0–septate, rare
1–septate, 25 per cent, 28–35 x 5.5–6.3μ
2–septate, 45 per cent, 26 x 6.3 (29–39 x 6.7)μ
3–septate, 30 per cent, 37 x 6.5 (30–41 x 6.3–7)μ

On red raspberry cane plug, culture fifty-five days old; conidia from a sporodochium:

Conidia: 1–septate, 63 per cent, 30 x 6.7 (20–34 x 5.5–7.4)μ
2–septate, 37 per cent, 33 x 6.8 (25–37 x 6.5–7.4)μ

On the same medium as above, culture one hundred and thirty-six days old; conidia from a sporodochium:

Conidia: 0–septate, few, 19 x 5.4μ (only a few measured)
1–septate, 30 per cent, 28 x 6.2 (20–32 x 5.2–6.8)μ
2–septate, 62 per cent, 33 x 6.5 (28–40 x 6–7)μ
3–septate, 8 per cent, 35 x 6.5 (31–40 x 6–7)μ

On hard lima-bean agar, culture eight days old; conidia from a sporodochium:

Conidia: 1–septate, 44 per cent, 30 x 6.3 (22–35 x 5.5–6.5)μ
2–septate, 49 per cent, 33.7 x 6.4 (29–39 x 6–6.6)μ
3–septate, 7 per cent, 36 x 6.5 (31–40 x 6–6.6)μ

On same medium and from same sporodochium as above, culture thirty-four days old:

Conidia: 0–septate, rare
1–septate, 46 per cent, 30 x 6.2 (23–37 x 5.4–6.5)μ
2–septate, 35 per cent, 33.6 x 6.3 (24–39 x 5.8–6.5)μ
3–septate, 19 per cent, 36.9 x 6.5 (32–39 x 6.1–7)μ

Average of the above measurements:

Conidia: 0–septate, rare, 19 x 5.4μ
1–septate, 42 per cent, 29.5 x 6.5μ
2–septate, 45 per cent, 32 x 6.4μ
3–septate, 13 per cent, 36 x 6.5μ

This organism, together with *Fusarium udum* var. *Solani*, was isolated by the writer only once, from a planting of diseased tissues of a potato tuber affected with a superficial dry rot, received from Long Island, New York.

By the shape and size of its conidia it very closely resembles *R. macrospora* Fres. (see Wollenweber 1913 c:222–223, 235, Pl. XX, A and B, and Pl. XXI, E), but differs mainly by the absence of oval, continuous conidia on aërial mycelium, and by the absence of chlamydospores.[61]

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[61] Chlamydospores were searched for very carefully in cultures on different media and of different ages, very old cultures being included, but were never observed. According to Wollenweber (1913 c: 208) such organisms, Ramularia-like but without chlamydospores, produce perfect forms of the genus Mycosphærella; although the organism described here under the name of *R. Solani*, when grown on various media, did not produce chlamydospores, nevertheless it has been retained in this genus because of its otherwise perfect resemblance to the other unquestionable species of Ramularia.

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Submitted for publication February 10, 1915.

EXPLANATION OF PLATES

All the plates were reproduced by three-color process from living cultures. The cultures were in all cases, unless otherwise specified, forty days old when photographed, and were grown at laboratory room temperature ranging from 20° to 25° C.

Cultures of Plates I to IV were, with a few specified exceptions, grown on hard potato agar with 10 per cent glucose, and were kept in a strong diffuse daylight and in air nearly saturated with moisture.

All cultures of Plates V to VII were on sterilized potato tuber plugs in test tubes which were kept at the above temperature but in very weak diffuse light.

PLATE I. FUSARIA OF POTATOES

Fig. 1. Fusarium Solani, from above
Fig. 2. F. striatum, from above
Figs. 3 and 4. F. Martii var. minus: 3, on acidified medium from below; 4, on hard oat agar from above
Figs. 5 and 6. F. coeruleum, from above and below
Figs. 7 and 8. F. oxysporum var. resupinatum, from above and below
Figs. 9 and 10. F. lutulatum var. zonatum, from above and below
Figs. 11 and 12. F. sclerotioides, in dark, from above and below

EXPLANATION OF PLATES

All the plates were reproduced by three-color process from life [illegible]. The cultures were in all cases, unless otherwise specified, [illegible] days old [illegible] photographed, and were grown at laboratory room temperature ranging from [illegible] to 25° C.

Cultures of Plates I to IV were, with a few specified exceptions, grown on hard potato agar with [illegible] of glucose, and were kept [illegible] diffuse daylight [illegible] saturated with moisture.

All cultures of Plates V to VII were on sterilized potato tuber plugs in test tubes which were kept at the above temperature, but in very weak diffuse light.

PLATE I. FUSARIA OF POTATOES

Fig. 1. Fusarium Solani, from above.

Fig. 2. F. [illegible], from above.

Figs. 3 and 4. F. Martii var. minus: 3, on acidified medium from below; 4, on hard [illegible] agar from above.

Figs. 5 and 6. F. coeruleum, from above and below.

Figs. 7 and 8. F. oxysporum var. resupinatum, from above and below.

Figs. 9 and 10. F. lutulatum var. zonatum, from above and below.

Figs. 11 and 12. F. sclerotioides in dark, from above and below.

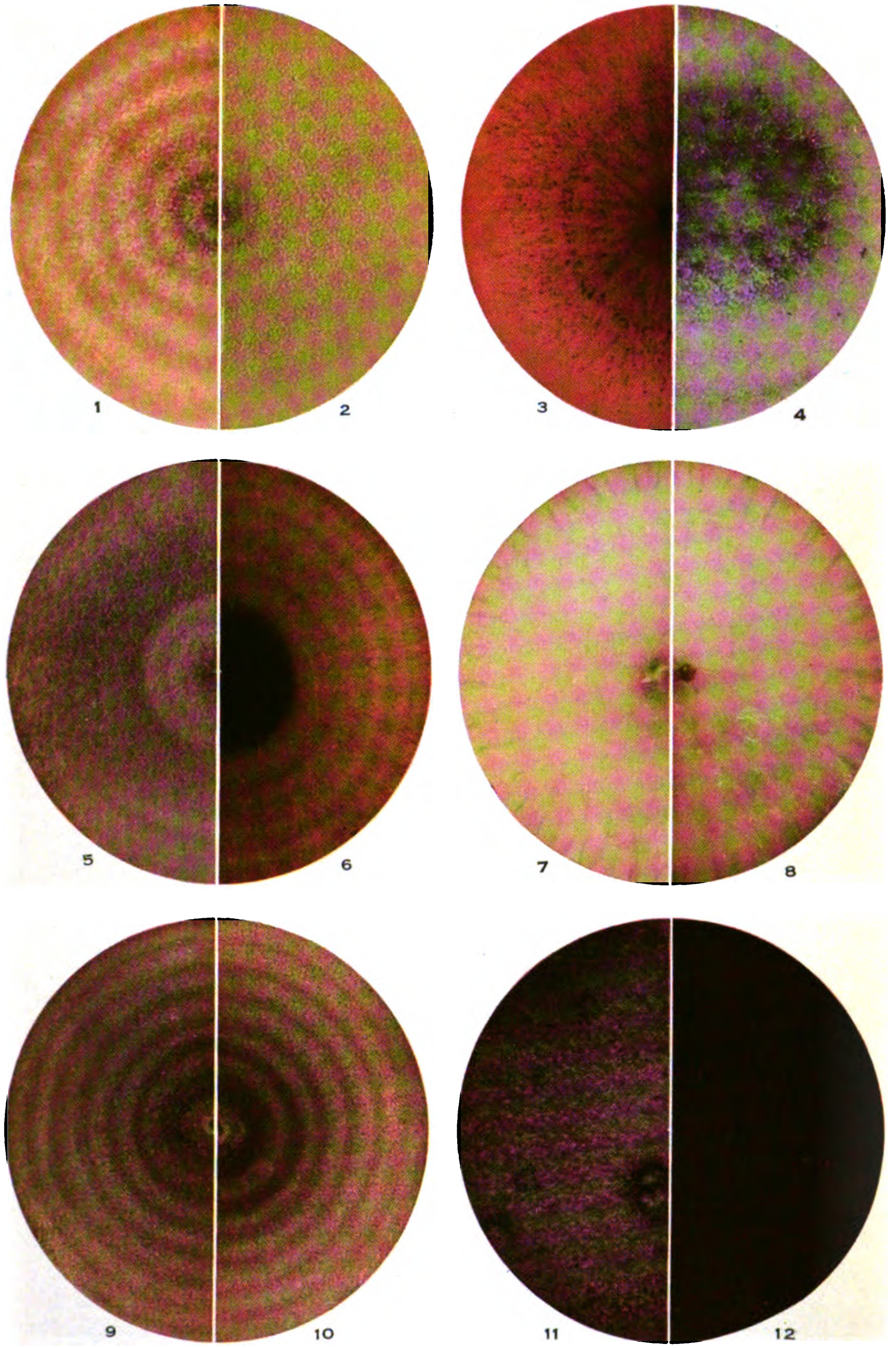

PLATE I—FUSARIA OF POTATOES

PLATE II. FUSARIA OF POTATOES

Figs. 1 and 2. Fusarium sclerotioides var. brevius, from above and below; 1, culture fifteen days old
Figs. 3 and 4. F. redolens var. Solani, from above and below
Figs. 5 and 6. F. lutulatum, from above and below; 6, culture on slightly acidified medium fifteen days old
Figs. 7 and 8. F. arcuosporum, from above and below
Figs. 9 and 10. F. lucidum, from above and below; fig. 9, culture fifteen days old, in dark
Fig. 11. F. subulatum, from above; hard oat agar
Fig. 12. F. subulatum var. brevius, from below, on slightly acidified medium

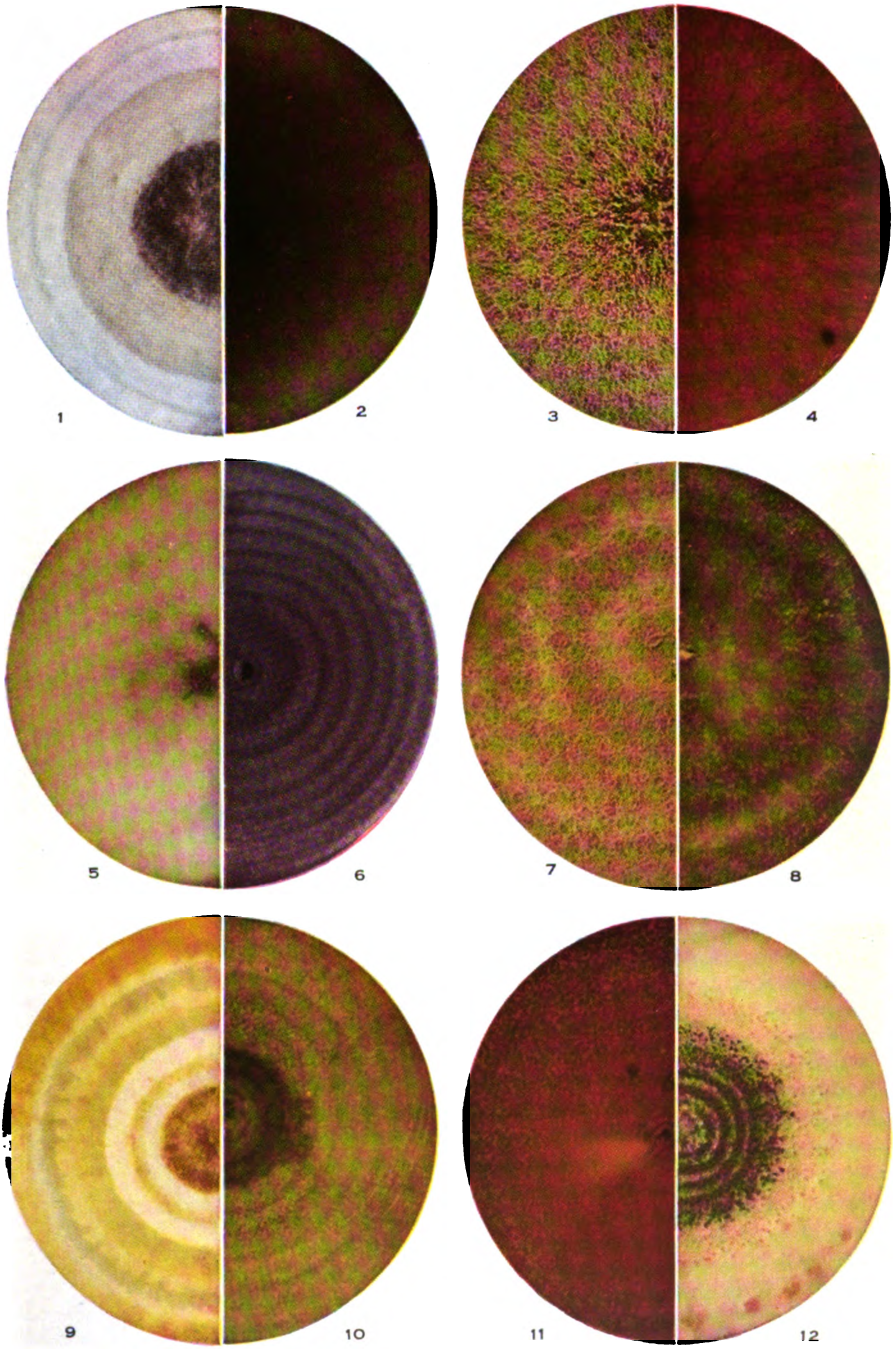

PLATE II—FUSARIA OF POTATOES

PLATE III. FUSARIA OF POTATOES

Fig. 1. Fusarium sporotrichioides, from above; in dark
Fig. 2. F. bullatum var. roseum, from above
Figs. 3 and 4. F. arthrosporioides, from above and below; in dark
Figs. 5 and 6. F. sanguineum var. pallidium, from above and below
Figs. 7 and 8. F. sanguineum, from above and below; in dark
Figs. 9 and 10. F. ferruginosum, from above and below
Figs. 11 and 12. F. clavatum, from above and below

PLATE III. FUSARIA OF POTATOES

Fig. 1. Fusarium sporotrichioides, from above; in dark
Fig. 2. F. bullatum var. roseum, from above
Figs. 3 and 4. F. arthrosporioides, from above and below; in dark
Figs. 5 and 6. F. sanguineum var. pallidium, from above and below
Figs. 7 and 8. F. sanguineum, from above and below; in dark
Figs. 9 and 10. F. ferruginosum, from above and below
Figs. 11 and 12. F. clavatum, from above and below

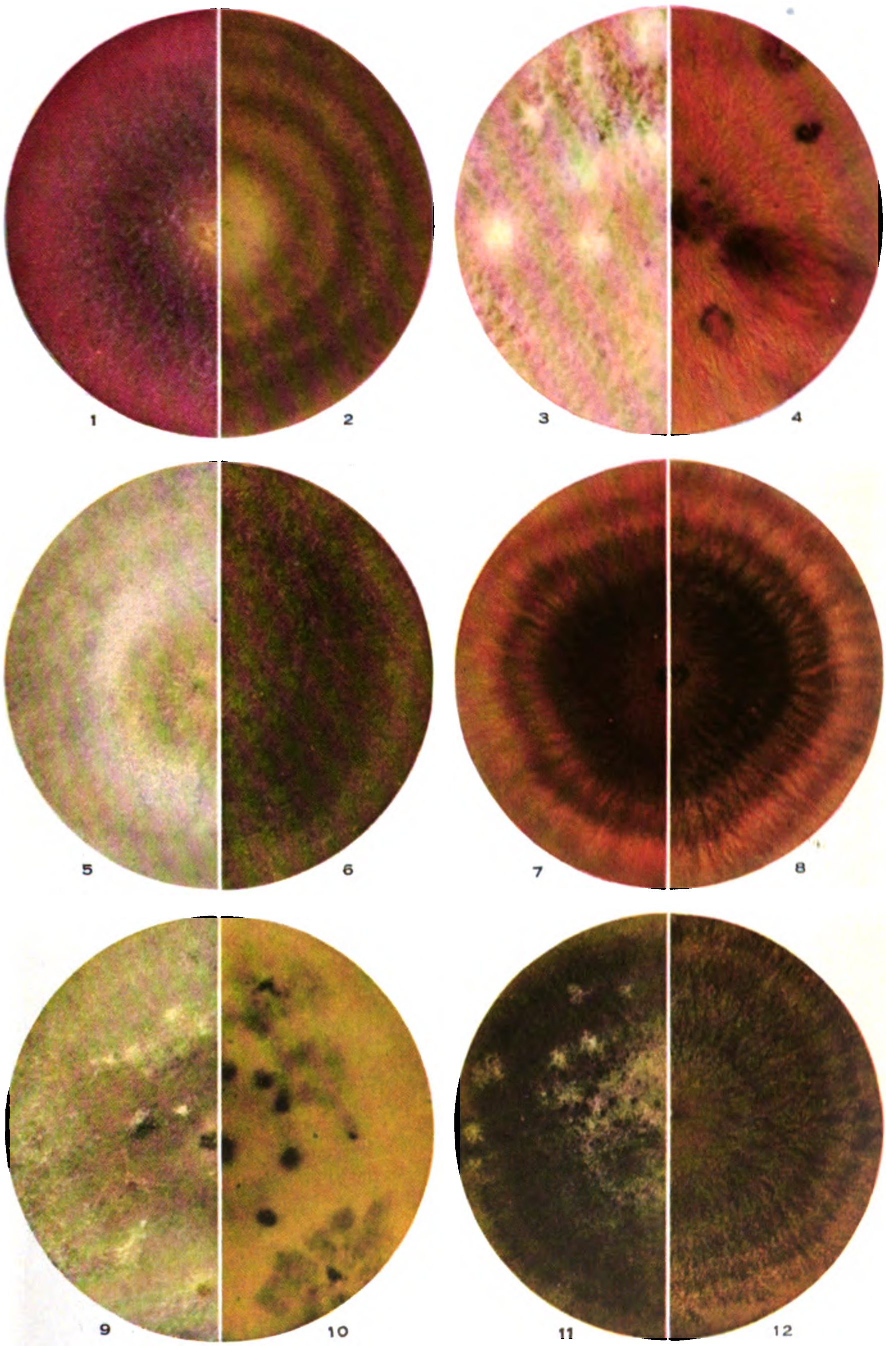

PLATE III—FUSARIA OF POTATOES

PLATE IV. FUSARIA OF POTATOES

Figs. 1 and 2. Fusarium culmorum var. leteius, from above and below
Fig. 3. F. subpallidum var. roseum, from above; on slightly acidified medium
Fig. 4. F. discolor, from below
Figs. 5 and 6. F. discolor var. triseptatum: 5, from above, in dark on neutral medium; 6, from above, in light on slightly acidified medium
Fig. 7. F. caudatum var. Solani, from above, neutral medium
Fig. 8. F. trichothecioides, from above
Fig. 9. F. culmorum from above, on hard oat agar
Fig. 10. F. culmorum var. leteius, from above, on hard oat agar
Fig. 11. F. discolor var. sulphureum, from above
Fig. 12. F. lucidum, from above, slightly acidified medium, fifteen days old

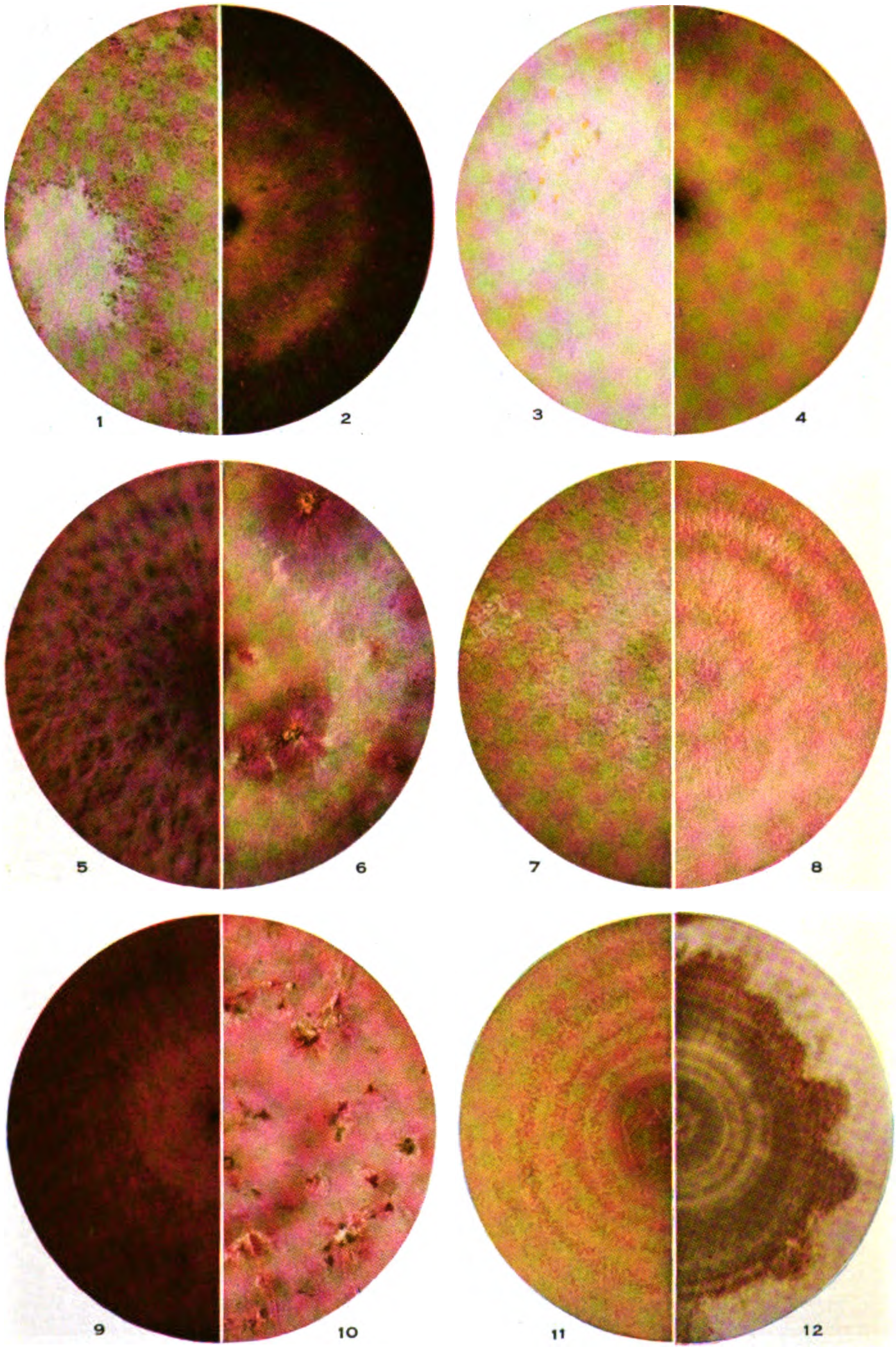

PLATE IV—FUSARIA OF POTATOES

PLATE V. FUSARIA OF POTATOES

Fig. 1. Fusarium sclerotioides
Fig. 2. F. redolens var. Solani
Fig. 3. F. lutulatum
Fig. 4. F. lutulatum var. zonatum
Fig. 5. F. oxysporum var. resupinatum
Fig. 6. F. oxysporum
Fig. 7. F. oxysporum var. asclerotium
Fig. 8. F. culmorum
Fig. 9. F. culmorum var. leteius
Fig. 10. F. discolor var. triseptatum
Fig. 11. F. discolor
Fig. 12. F. subpallidum

PLATE V—FUSARIA OF POTATOES

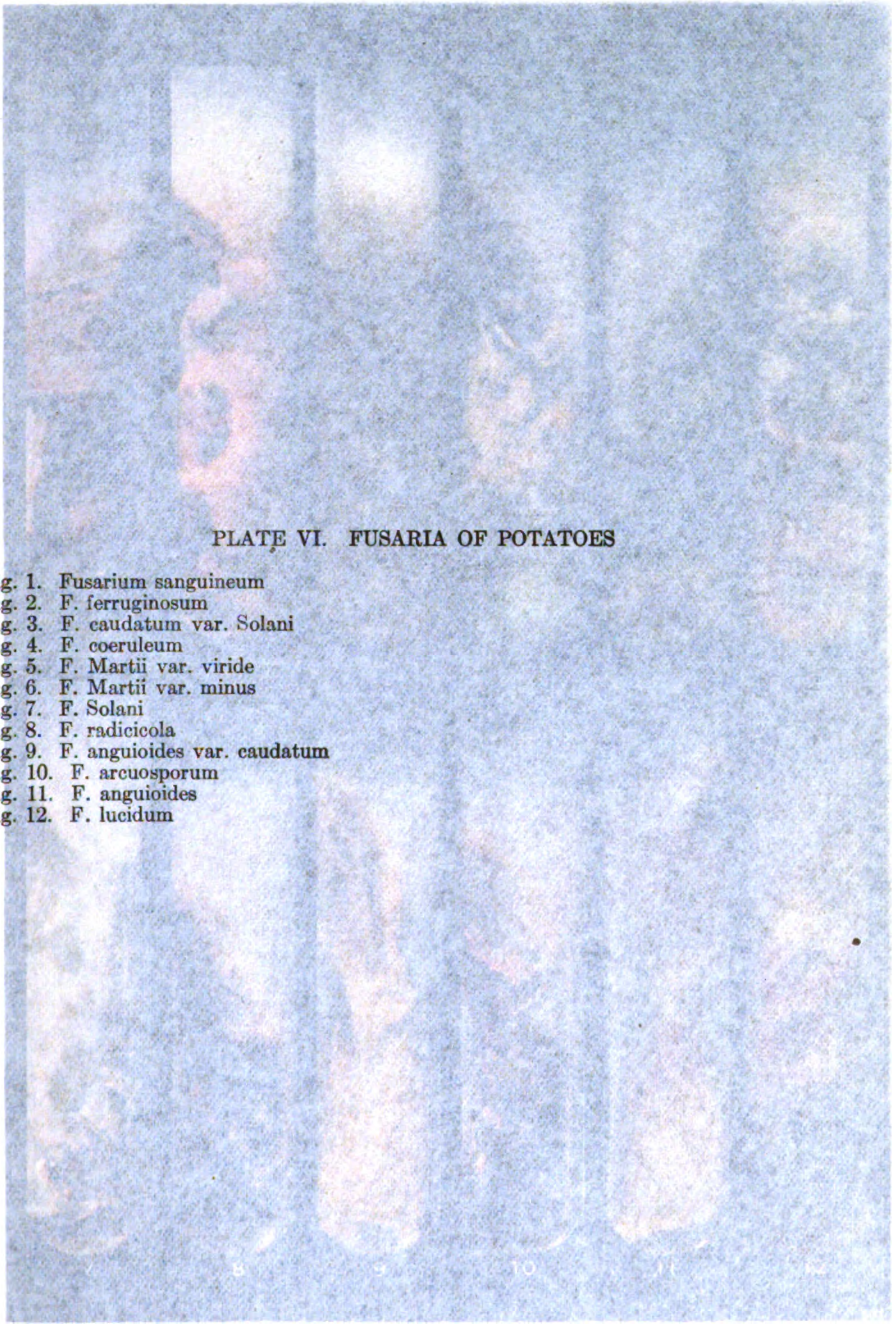

PLATE VI. FUSARIA OF POTATOES

Fig. 1. Fusarium sanguineum
Fig. 2. F. ferruginosum
Fig. 3. F. caudatum var. Solani
Fig. 4. F. coeruleum
Fig. 5. F. Martii var. viride
Fig. 6. F. Martii var. minus
Fig. 7. F. Solani
Fig. 8. F. radicicola
Fig. 9. F. anguioides var. caudatum
Fig. 10. F. arcuosporum
Fig. 11. F. anguioides
Fig. 12. F. lucidum

PLATE VI—FUSARIA OF POTATOES

PLATE VII. FUSARIA OF POTATOES

Fig. 1. Fusarium truncatum
Fig. 2. F. clavatum
Fig. 3. F. subulatum var. brevius
Fig. 4. F. subulatum
Fig. 5. F. metacroum
Fig. 6. F. effusum
Fig. 7. F. sanguineum var. pallidium
Fig. 8. F. falcatum var. fuscum
Fig. 9. F. arthrosporioides var. asporotrichius
Fig. 10. F. biforme
Fig. 11. F. arthrosporioides
Fig. 12. F. diversisporum, pseudopionnotal stage

PLATE VII—FUSARIA OF POTATOES

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AGRICULTURAL EXPERIMENT STATION
OF THE COLLEGE OF AGRICULTURE

SENILE CHANGES IN LEAVES OF VITIS VULPINA L. AND CERTAIN OTHER PLANTS

By HARRIS M. BENEDICT

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CONTENTS

SENILE CHANGES IN LEAVES OF VITIS VULPINA L. AND CERTAIN OTHER PLANTS

SENILE CHANGES IN LEAVES OF VITIS VULPINA L. AND CERTAIN OTHER PLANTS[1]

HARRIS M. BENEDICT

The inevitable onset of senile deterioration after a relatively short period of activity is the basic tragedy of life. And yet, in comparison with the amount of research that has been directed toward the discovery of the causes of living activities, very little has been done to determine the causes of the approach of senility. Biologists seem to have tacitly agreed to find out what causes the living machine to run before they seek the reasons why it stops. This attitude has been further encouraged by the belief that the causes of senility could not be understood until the laws governing living action were determined.

The work that has been done is naturally of two kinds — attempts to determine what changes of function and structure are characteristic of the increasing age of an organism, and the promulgation of various theories as to the causes of senility. So much of the work on senility has been carried on with animal organisms that this field in plant life may be said to be unentered; the reasons for the neglect of plants in this respect will be dealt with later. It seems advisable, therefore, as the only available basis for approaching this problem in plants, to prepare a brief summation of the results of the investigations on senility in man and in the lower animals.

SENILE CHANGES IN ANIMALS

The chief difficulty in the search for the changes due to senility is the constant presence in the living organism of modifications of tissue and function produced by unfavorable conditions other than age, both internal and external. Much of the work on record has been marred by inadequate appreciation of this fact. Furthermore, the older the organism becomes, the greater is the probability that effects of these other adverse influences will be present. It follows, therefore, that the condition of extreme senility, which has been commonly studied, is actually the most difficult stage to investigate for changes due to age alone. Those theories of

[1] Laboratory of Plant Physiology, Cornell University. Contribution No. 15.

senility that are more or less fanciful have been based on conditions found in extremely senile animals.

It is now generally recognized that the forces causing senility and natural death are not dormant in early life and later roused to action, but instead are at work from the time when embryonic development begins until death occurs, and, in fact, as Minot (1908)[2] has so efficiently emphasized, are most active at the beginning. Therefore, in view of the difficulty involved in the investigation of extremely senile tissue and of the constant presence of senile changes throughout life, the importance of comparison between younger stages is manifest; and in the accompanying summary of the results of investigations, first rank is given to those characteristics that can be shown to undergo continuous change from the beginning. The results of the various essential researches into senility in animals are here classified under three headings: (1) Senile changes in physiological activities; (2) Senile changes in the structure of animal organs; (3) Senile changes in the structure of animal cells. It is evident that in this classification there will be some overlapping, but its advantages in permitting a concise and clear-cut arrangement of the various results of different investigators outweigh this defect.

This very condensed summary of the results of investigations on animal senility gives at least a conception of the difficulties involved. Evidently, however, a start has been made in the various avenues of approach to the problem.

SENILE CHANGES IN PHYSIOLOGICAL ACTIVITIES

Deterioration evident from the beginning

Decrease in rate of growth.— The most obvious characteristic of senility is a decrease in rate of growth. The rate of decrease found in animals thus far investigated may be illustrated by figures obtained from the study of human development. Hertwig (1906) estimates that the human ovum has a volume of 0.004 cubic millimeter, while the size of the child at birth is 4,000,000 cubic millimeters — an increase of 100,000,000,000 per cent in nine months. According to Minot (1908) the gain in weight during the same period is 500,000,000 per cent. It is evident that the rate of growth of the embryo is extraordinary. Mühlmann (1900 and 1901) states that the rate of growth of the embryo is greater during the

[2] Dates in parenthesis refer to bibliography, page 363.

first month than the second, indicating that a decrease in the rapidity of growth sets in even before birth.

Data are abundant regarding the yearly percentage of gain in weight made by children. The average increase in weight during the first year, relative to the weight at birth, shows a percentage of increase of 200; that of the second year only from 22 to 30; that of the third year from 14 to 20. From the fourth year to the twenty-fifth the rate of increase is subject to irregular variations, mostly downward. From the twenty-fifth year to the fiftieth there is little or no change in weight, on the average. After fifty years, as a rule, there is a loss in weight. Detailed tables, with graphs showing the steady decrease in rate of growth with increasing age, can be found in Donaldson's papers (1895, 1906, and 1908); while Minot gives carefully selected data from various sources, to which he has added graphic illustrations.

It is evident that the rate of growth in animals thus far investigated declines from the very beginning of individual life, and that this is a manifestation of inherent forces which tend to slow vital activities.

Decrease in rate of respiration.— The rate of respiration in mammalian animals can be investigated only in the years after birth. There is then evident a gradual decrease of the same general type as that found for growth. In the last stage of life a slight increase occurs, similar to that shown in the heartbeat and explained under that topic.

Decrease in rapidity of heartbeat.— The following figures are taken from a compilation by W. T. Porter, quoted in Minot's book, and refer to man:

Age	Mean frequency of heartbeat per minute
Fetus	140
1st month	134
5th year	103
10th year	91
15th year	82
20th year	74
25th year	72
55th year	72
65th year	73
80th year	79

A curve graphically representing the change in pulse rate has been plotted and is shown in figure 52. Here again there is seen a more rapid decrease in early life than later. It is evident that the rates of growth, of respiration, and of heartbeat are but the most obvious indicators of the degree of metabolic activity of the animal protoplasm.

The increase in rate of respiration and of heartbeat that occurs in the last years of life is an example of a struggle between the depressing force of senility and the accelerating stimuli exerted on the lungs and the heart by the other organs of the body. The organs composing the body of an animal are so interrelated that a need in one produces a stimulus to action in any organ which can satisfy that need. In the last years of life the organs supplied with oxygen and relieved of harmful waste products by the failing lungs and heart, reach such a condition that the resulting stimuli become so powerful as to more than neutralize for a time the effects of senility in slowing the beat.

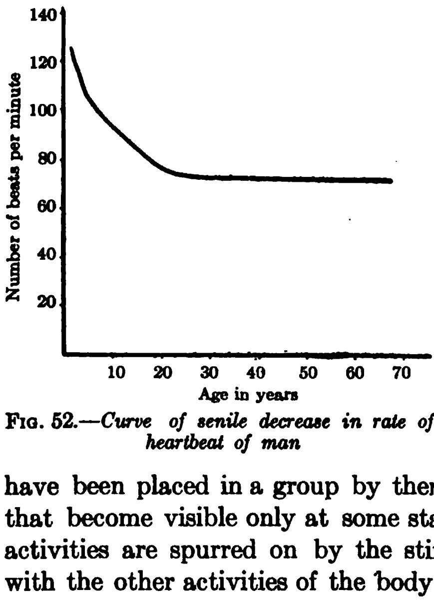

FIG. 52.—*Curve of senile decrease in rate of heartbeat of man*

This power of one part of the body to stimulate another organ leads to many cases of apparent suppression of the effects of senility, especially in the stages of youth and maturity of the animal body. Contrary to the usual custom, these have been placed in a group by themselves as those evidences of senility that become visible only at some stage later than that of youth. These activities are spurred on by the stimuli resulting from their interaction with the other activities of the body. For example, the increase of muscular strength and coordination due to the interaction of the muscular and nervous systems, which characterizes the first third of human life, is made possible.

Deterioration appearing later in life

The first four types of deterioration given as appearing later in life deal with activities in contact with the external world, and are therefore the most obvious.

Deterioration in rapidity and coordination of movement.— According to Mühlmann (1901) the musculature of man ceases to grow at about the age of thirty-six, but the experience of highly trained athletes indicates a considerably earlier appearance of decrease in muscular power and co-ordination.

Deterioration in the powers of special sense.— The tendency toward deafness and failing sight are common manifestations of deterioration in the powers of special sense.

Deterioration in efficiency of excretion.— While the belief that deterioration in efficiency of excretion is always present is based partly on theoretical considerations rather than on extensive tests, there can be little doubt of its truth. In dealing with the various theories of senility this function will be again referred to.

Deterioration in reproductive power.— Decreased reproductive power is more marked in the female than in the male.

Deterioration in all the internal activities characteristic of living animals.— There can be little question of the presence of a general deterioration in internal activities of animals, even in the central nervous system, but exact investigations are wanting.

SENILE CHANGES IN THE STRUCTURE OF ANIMAL ORGANS

The changes discussed below seem to be of a type not appearing in early life.

Decrease in the size of all organs, due to atrophy of the cells and of the intercellular substance.— Douaud (1867), Kölliker (1897), and others since their times, have investigated the senile atrophy in muscles. Metchnikoff (1908) presents further studies in which he claims that the destruction of the contractile power is produced by a special kind of phagocyte. Senile atrophy of the brain has been investigated in man and in bees by Hodge (1895), who found that the decrease in size was largely due to actual death and disappearance of cells, as well as to shrinkage of the living cells. In all cases when the organs of animals in the condition of extreme senility have been studied, the appearance of loss and degeneration of cells is presented. The ductless glands — the thyroid, for example — show this degeneration and have been utilized by Lorand in the formulation of a theory of senility.

Hardening and thickening of the lining of vessels, lungs, and digestive system, and hardening of cartilage.— Arterial sclerosis has long been associated with senility, even to the extent of being considered a cause (Demange, 1886). The hardening and thickening of all lining membranes is believed to accompany old age, but the experiments have been too few to decide the matter. There seems little question, however, but that such absorbing and excreting surfaces become more rigid with age, and probably less efficient. The hardening of the cartilages, with consequent decrease in the flexibility of the joints and the forward curving of the spine, is universal in man.

Increasing weakness and brittleness of bone.— While other tissues are gaining an undue amount of calcareous material, the strengthening lamellæ of the interior parts of the bone are disappearing and in consequence the bone becomes weaker. The remainder of the bone increases in its calcareous content and decreases in its living substance, thus becoming more brittle as well as weaker.

Tendency of connective tissue to encroach on the higher tissues.— The increasing tendency in old age for injured cells of nerves, muscles, or other highly specialized tissues to be replaced by connective tissue, which is the least highly specialized tissue, has been explained in a number of ways. The generally accepted view is that given by Hertwig (1906). He pictures a single-celled organism as carrying on the functions necessary to itself alone, and thus being acted on only by cytological laws. The cell in a multicellular organism, on the other hand, is subject to both the cytological laws required for its own nourishment and to the organotypical laws governing those of its activities that nerve the whole organism of which it is a part. Hertwig believes that the higher the differentiation of a tissue, the more complete is its obedience to the organotypical laws. As age increases, the organotypical laws weaken, and the lowest tissue, which is least subject to them, is the first to throw off the yoke and attack the surrounding organs. This view is interesting, but purely theoretical.

While the discussion of these four classes of change in organs seems a very inadequate treatment of the effect of senility on animal organs, it is not an unfair expression of the present state of knowledge of these changes. Other changes have been mentioned, but there is even less evidence for them than for those here given.

SENILE CHANGES IN THE STRUCTURE OF ANIMAL CELLS

All the preceding changes must of course be merely magnified outgrowths of changes occurring in the cell. Considering the investigations made as to the effect of senility on the cell itself, it may be seen that very little has been done toward an actual understanding of this problem.

Changes evident from the beginning

Decrease in size of nucleus.— Hodge (1895) found the nuclei of the spinal ganglia to be smaller in the senile than in the young condition. Hertwig (1904 and 1906), however, regards the extreme size of the nucleus characteristic of certain protozoan stages and of the animal ovum as evidence of dormancy rather than of rejuvenescence. Minot gives the interesting evidence that while investigators of the embryonic development of animal eggs make no statement regarding the fact, their drawings invariably show a rapid decrease in the size of the nucleus.

Increase of cytoplasm in amount and in differentiation.— That cytoplasm increases in amount and in differentiation was first emphasized by Minot (1891), who considers the fact of prime importance. Eycleshymer (1904) gives the following data regarding the proportion of cytoplasm to nucleus at different ages of Necturus muscle:

Length of body......	8 mm.	17 mm.	26 mm.	Adult, 230 mm.
Proportion of cytoplasm to nucleus....	2,737–1	4,318–1	8,473–1	23,379–1

The great change in the structure of the cytoplasm by which the highly specialized cells are developed from the undifferentiated cells or the morula stage, is evident.

Changes appearing later

Nucleus irregular in form, and staining like cytoplasm.— Irregularity in form of the senile nucleus, and its staining like cytoplasm, was observed by Hodge (1895) in the spinal ganglia of man.

Local degenerations in cytoplasm.— Cytoplasm with many local degenerations, indicating that portions were undergoing various forms of degeneration, is described for ganglion cells by Hodge (1895). Various forms

of fatty degeneration are found in senility in cartilage and in other body cells, indicating loss of power of assimilation or inefficient katabolism.

Accumulation of pigment in the cytoplasm.— Hodge (1895) found a difference in accumulation of pigment in the cytoplasm between young and old cells of the spinal ganglion of man. It has been stated that pigments are excretory masses and that they increase with age.

Deterioration of nucleolus.— The nucleolus diminishes in mass and in staining power. It was Hodge also who first pointed out this fact. Hertwig (1904) emphasized the relation between size of nucleolus and cell activity.

INVESTIGATIONS ON SENILITY IN PLANTS: GENERAL

REVIEW OF LITERATURE

A review of the changes that have been discovered in perennial plants as a result of senility shows that no investigations comparable to the ones above cited have been made. Such statements as are commonly found regarding the effect of age are based on casual observations rather than on investigations. The reason for this seems to be the tacitly accepted belief that, since new leaves and twigs and roots are constantly being formed from persisting embryonic cells, senility as present in animals is out of the question, and the term as used for plants means merely that conditions have become so unfavorable that the growing parts are killed.

This view has been further encouraged by the very great age attained by certain trees, as, for example, the sequoias, the cypresses of Mexico, and the baobab of Cape Verde — the last named estimated by Adanson to be over five thousand years old. Therefore, the idea that trees have the potential power to live forever if the conditions due to their increasing size — injury from winds, greater distance from the soil, and other harmful effects — could be prevented, is not so much formally accepted as passively assumed.

Such statements as have been published are almost entirely from the pens of fruit growers. Among the first of which the writer has found record are the papers by Thomas Andrew Knight, the justly famous English horticulturist, to which reference will be made later. Zorn (1890), nearly one hundred years later, gives about the same list of effects of age, and his list in its conclusion does not fall far short of present knowledge. He says that in old age fruit trees bear less, are later in maturing their

fruit, and are more likely to be attacked by scale and disease. He states further, regarding pear trees, that the epidermis is likely to blister, that the trees are less able to withstand cold, and that the fruit is small, deformed, unpalatable, and with more hard flecks in the flesh.

The botanist and the horticulturist of to-day add nothing to Zorn's list. The question whether true senility occurs in perennial plants, therefore, is still an open one. The changes spoken of by Zorn and by more recent writers may be effects of disease of external origin or the result of increase in size of the tree, not real results of senility. De Candolle (1876) investigated the question whether the time of leafing was related to the age of the tree, and decided that the age was negligible compared to the climatic conditions. His results in this one particular seem to have been much more widely applied than he probably intended.

IMPORTANCE AND SIGNIFICANCE OF THE PROBLEM

The importance of determining whether there is any real senile change in plants lies not alone in the scientific need for such knowledge, but also in its direct bearing on the long-disputed question regarding the effect of continuous vegetative propagation of seed-producing plants. For if the new growth from which cuttings are made has not been affected by the time that has elapsed since the plant came from the seed, then its tissue is no more senile than seedling tissue; if, however, the meristematic tissue, which has been so actively growing and dividing since it originated in the embryo sac of the parent plant, has itself suffered the senile deterioration that accompanies activity in animal cells, then the tissues arising from this meristematic tissue must partake of its senility.

The processes of division and growth require considerable expenditure of energy; therefore, if the plant cell is not entirely immune to senile deterioration, the meristematic as well as the specialized tissues should undergo such change. In fact, in the ontogeny of the animal, senile deterioration is most rapid at the time when specialization is least, when the only activities of the cells are division and growth. There is no inherent reason, therefore, why meristematic and cambial cells should be put in a different class from that of specialized cells as regards the possibility of senile degeneration.

It may be true — no exact comparisons as to this point are on record — that the meristematic cells have a greater proportion of nucleus to cyto-

plasm than have the specialized cells which develop from them, and thus, according to the views of Minot and Hertwig, the former would be potentially younger; but that is not the point at issue. The real issue is, provided always that the evidences of senile deterioration found in animal cells may serve as a guide to senility in plant cells, whether the meristematic cells of the older perennial differ from those of the seedling in this or in other respects.

It may be advisable to again refer at this point to an argument which possibly has had some weight; namely, that the very great age attained by certain trees is an indication that they must be immune from senility as this is known in animals. Some of these trees have lived for five thousand years, or many times the age to which man has attained. This argument can be applied to the human being with most interesting and reassuring results. The rotifer *Pleurotricha haffkini*, studied by Metchnikoff (1908), has a total span of life of three days. Applying the above argument, a child who reaches the age of three months, having existed forty times as long as another organism, may be assumed to be immune from the stern decree of senile laws. The elephant lives one hundred thousand times as long as the rotifer; and in general the extraordinary differences in duration of life found in animals in which undoubted senility occurs, robs the fact that plants in general are possibly longer-lived than animals of any significance as regards senility.

INVESTIGATIONS ON SENILE CHANGES IN LEAVES OF VITIS VULPINA L. AND CERTAIN OTHER PLANTS

PLAN OF INVESTIGATION

It would seem that the logical method of attacking the problem is by a careful comparision of the same organ in young and old plants of the same genus for evidences of senile deterioration in structure or function. It was considered desirable to choose a plant that was marked by extreme vigor in putting forth new growth each year, in order to minimize as much as possible the chance of the presence of unfavorable conditions other than age. The wild grape, *Vitis vulpina* L., answered this requirement. Any one who has noticed the long shoots and luxuriant foliage produced by this vine each spring must feel that the conditions for its nutrition and general health are good, and that the harmful results usually ascribed to the increasing size of a plant are not in this case serious.

For several reasons the organ selected was the leaf, not the meristematic tissue itself. In the first place, not only must the presence of any change in the meristematic cells effect changes in the specialized cells produced from them, but the effects must be more evident than the conditions that produced them, for the same reason as that accounting for the fact that any internal differences between two seeds will be displayed much more plainly in the plants that are produced from them than in the seeds themselves. Thus, changes too minute to be perceived in the meristematic cells might produce very obvious differences in the mature leaf. In the second place, the leaves are renewed each year, and therefore, according to the commonly accepted conception, should be entirely immune from any sign of age; or, to express this in another way, any sign of senility found would be of exceptional importance in its bearing on the problem. In the third place, the leaf is more accessible than other organs.

The many careful researches that are on record regarding the effect of all factors excepting age on the structure and functions of the leaf seemed to justify the opinion that if any differences were found it would be possible to decide whether they were due to one of these factors or whether they must be referred to age.

Leaves from young and old vines of *Vitis vulpina* were collected and were subjected to a preliminary examination by means of a hand lens. The most striking difference apparent was observed in the venation. On holding the leaf blades to the light, the meshes formed by the most minute veinlets appeared larger in the leaves of young vines than in those of old ones. A difference so marked that it could be discerned with a hand lens would be capable of utilization in the field and of practical application in orchard and nursery. Therefore an investigation was begun of the size of the meshes in leaves of vines of different ages.

Collection and preparation of material

In order that the effects of differences in exposure to light and wind and of differences in nutrition might be reduced as much as possible, the country in the vicinity of Ithaca, New York, and of Cincinnati, Ohio, was searched for vines of different ages growing near one another under the greatest possible similarity of external conditions. It proved to be more difficult than was expected to find such paired vines, but at last about twenty pairs were found.

These vines were numbered, and their relative ages were obtained by sawing out a thin slice from one side at the base of the stem. For comparative purposes ten leaves were collected from each vine, as well as cuttings and material for permanent mounts. Care was taken in selecting the leaves to get only fully matured, healthy, normal specimens. Since conditions of humidity and temperature are different at different levels above the ground, the leaves were taken from the lower parts of the vines, not above eight feet from the ground. The effect of light exposure has been shown by Schuster (1908) to be a definite one, and care was taken that all selected leaves were such as had full exposure to the sky, of the same character for each of the paired vines.

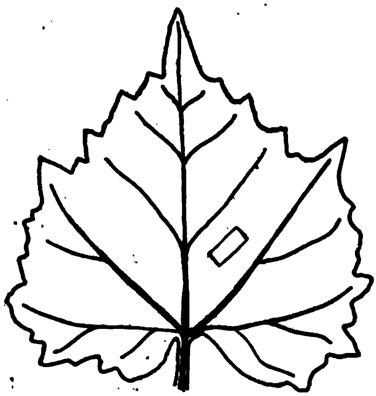

FIG. 53.—*Part of the leaf removed for photographing*

The collected leaves were taken immediately to the laboratory, measured as to length, breadth, and area, and weighed. The venation was then photographed in the following way: A heavy black paper was pasted to a clean glass plate, four by five inches in size. Ten openings, approximately four by ten millimeters in size, were then cut in the black paper. From the same part of each leaf (Fig. 53) pieces a little larger than the openings were cut, and these were laid over the openings, so that each of the ten leaves was represented. A clear glass plate was then laid over all, and the whole was bound together by elastic bands, placed in the negative holder of an enlarging camera, and photographed at an enlargement of three diameters. Negatives showing the veinlets clearly were obtained after some practice, and from these negatives velox prints were made.

The appearance of a leaf, viewed by transmitted light, is as a vast number of aggregations of photosynthetically active cells, occupying the meshes of the network of veinlets. The size of these aggregations seems to the writer to be of more direct physiological significance than the arbitrary standard introduced by Zalenski — the combined length of the veins in one square millimeter of leaf surface — and therefore

determinations of the area of the cell aggregates have here been employed.

The average size of these aggregates, which will hereafter be called vein islets, was determined by dividing the area of each of the openings in the paper by the number of vein islets that filled it in the photograph. The counting was done under a lens, and a sharp needle was used to prick each vein islet as it was counted on the photograph.

INFLUENCE OF CERTAIN FACTORS ON VENATION

While the literature on the venation of leaves is very extensive, most of it is concerned with the development, structure, and function of the large veins — the midrib and its main branches. Only one phase of these investigations is directly important to the present problem, and that is the result of the controversy over the question whether the veins follow a course in the leaf entirely predetermined by heredity, or whether external conditions while the leaf is expanding can exert an influence.

The paleontological botanists, as represented by von Buch (1852), went so far as to say that, no matter how much the leaf might expand, no more nerves could arise than those present in the leaf while in the bud. The attack on this idea began with the discovery by von Nägeli (1855) that in the leaves of *Aralia spinosa* the nervature was not completely performed in the bud but arose in part later. Prantl (1883) showed that in many dicotyledons, during the expanding of the leaf, the development of new nerves took place in the direction of the greatest expansion. Deinega (1898), with further evidence obtained from the study of both monocotyledons and dicotyledons, established the fact that the nervature of the leaf is not performed in the bud to any great degree.

It still remained to be proved, however, that external conditions exert an undoubted effect on the nervature as it is laid down in the expanding leaf. While a long list of investigators have determined the effect of light and shade, dryness and moisture, on various structures of the leaf, practically no studies had been made regarding the effects of these external factors on venation until the work of Schuster (1908). It is true that a paper by von Zalenski (1902) was published, in which it was shown that in plants of the same genus a species inhabiting a dry location has a greater development of the finest nerves than another species inhabiting a wet location. Von Zalenski found that *Trifolium lupinaster*, which lives in a

dry situation, has a combined length of veins to the square millimeter of leaf blade of 1065 millimeters; while *Trifolium medium*, a moisture-loving plant, has a length of veins of but 460 millimeters. This, however, does not eliminate the effects of heredity. Schuster's investigation, on the other hand, was a detailed study of the effect of definite environmental factors on the same species. His results will be referred to frequently in the course of this paper.

The study of the arrangement of the finest veins of the leaf has the advantage that these veins are directly in contact with the active cells of the leaf, and must therefore be influenced by the state of the activities of these cells. The direct stimuli causing the development of branches from the sides of the existing veins, which thus subdivide the leaf blade, are not yet definitely known, but they must be affected to some degree by the conditions of the cells in the area into which the new branches penetrate. This matter will be taken up later. It is referred to here in order to emphasize the fact that the arrangement of the nerves in the leaf is related to the activities of the other cells of the leaf.

Uniformity in size of vein islets on different parts of a leaf

Schuster (1908) states that there is a definite uniformity as regards venation in all parts of the leaf, except close to the midrib and at the apices. Many tests were made of different parts of the same leaf of *Vitis vulpina* and a variation of less than three per cent was found. One test on a leaf of vine 2 gave the following figures:

	Square millimeters
Average of areas of five pieces from the right side....	0.4560
Average of areas of five pieces from the left side......	0.4567
Largest average of one piece from either side........	0.4613
Smallest average of one piece from either side......	0.4511

In other words, the largest average found was one per cent above the average for the whole leaf, while the smallest was one and one-tenth per cent below, and this may serve as a typical example.

Influence of size of leaf blade on size of vein islets

Schuster's results indicate that the relation between the size of the leaf and the combined length of veins in a given area is not of marked impor-

tance. The writer's measurements with *Vitis vulpina* also indicate that the size of the leaf has comparatively little effect. The figures in table 1 may be considered as typical:

TABLE 1. AREA OF VEIN ISLETS IN LEAVES OF DIFFERENT SIZES ON THE SAME PLANT. VINE 29

Number of leaf	Breadth of leaf (centimeters)	Length of leaf (centimeters)	Area of leaf (square centimeters)	Area of vein islets (square millimeters)
1	11	14	108	0.3762
2	17	16	190	0.3663
3	12	12	101	0.3818
4	11	11	85	0.3597
5	13	13	117	0.3669
6	14	14	117	0.3733
7	13	15	127	0.3681
8	15	17	179	0.3703
9	17	21	250	0.3777
10	14	15	147	0.3784

It seems at first thought so natural to suppose that the size of vein islets would be larger in the larger leaves, that a series of leaves was collected from vines ranging in age from seven to eleven years. The size of each leaf and that of its vein islets were measured, and the results are presented in table 2 and graphically represented in figure 54.

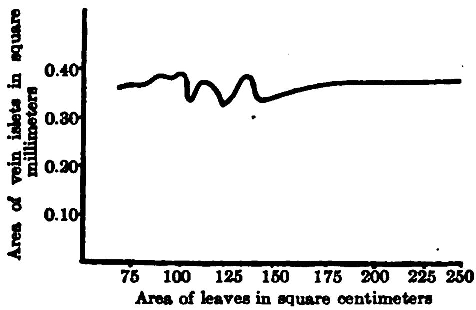

FIG. 54.—*Curve showing that size of leaf does not determine size of vein islets*

It is evident, therefore, that the formation of new veinlets keeps pace with the expansion of the leaf. A most striking example repeatedly found in another plant may be of interest here. Less than ten feet apart stood two trees of *Tilia americana*, one three inches in diameter, the other fourteen inches. The larger tree had been cut down, and from the stump were

TABLE 2. AREA OF VEIN ISLETS IN LEAVES OF DIFFERENT SIZES FROM VITIS VINES WITH FROM SEVEN TO ELEVEN RINGS

Number of leaf	Area of leaf (square centimeters)	Area of vein islets (square millimeters)
1	73	0.3580
2	77	0.3691
3	85	0.3694
4	92	0.3814
5	96	0.3761
6	101	0.3818
7	105	0.3812
8	109	0.3207
9	112	0.3669
10	116	0.3612
11	123	0.3391
12	126	0.3186
13	131	0.3217
14	137	0.3716
15	142	0.3197
16	147	0.3263
17	178	0.3703
18	190	0.3663
19	250	0.3777

growing several thick water sprouts. The relative size of the huge leaves growing on the water shoots and on the small tree was determined, as well as the size of the vein islets, with the following results:

	Area of leaf (square centimeters)	Area of vein islets (square centimeters)
Smaller tree	30	0.04
Water sprouts	1,560	0.02

The larger leaves had the smaller vein islets. The marked decrease in size of the vein islets is due to age. Similar results have been obtained from leaves borne on water sprouts of other varieties of trees.

Influence of thickness of leaf on size of vein islets

While very great differences in thickness of the leaves were not expected to occur, it seemed necessary to determine whether this factor might

affect the size of the islets. This was investigated by collecting various leaves from vines of approximately the same age, the variation being a few years, and determining the weight per 100 square millimeters of leaf blade of each leaf and the size of the vein islets of each. The difference in weight is taken to mean differences in thickness, as all the leaves were picked at the same time of day. The data obtained are given in table 3:

TABLE 3. AREA OF VEIN ISLETS IN LEAVES OF DIFFERENT THICKNESSES

Number of leaf	Weight of 100 square millimeters of leaf (grams)	Area of (islets square millimeters)
1	0.83	0.3597
2	0.87	0.3669
3	0.89	0.3663
4	0.91	0.3207
5	0.99	0.3818
6	1 04	0.3777
7	1.16	0.3263
8	1.20	0.3197
9	1.36	0.3217
10	1.43	0.3696
11	1.51	0.3612
12	1.61	0.3667
13	1.63	0.3580
14	1.67	0.3716
15	1.69	0.3691

Influence of such differences in light as are found in nature on the size of vein islets

Schuster found that the effect of light on the veins was not the same in all plants. The leaves of some plants showed an increased amount of venation (smaller vein islets) when grown in the shade, others were not affected, and still others showed a decrease. One of the plants investigated by Schuster was *Ampelopsis veitchii*, a genus of the *Vitaceae*, and this showed, if anything, a tendency to decrease in amount of venation in strong light (resulting in increase in size of vein islets). The same tendency was found to be true in *Vitis vulpina* to a slight degree (table 4).

TABLE 4. EFFECT OF LIGHT AND SHADE ON SIZE OF VEIN ISLETS. VINE 53

Leaves growing in shade (number of leaf)	Area of islets (square millimeters)	Leaves growing in light (number of leaf)	Area of islets (square millimeters)
1	0.1511	1	0.1543
2	0.1376	2	0.1678
3	0.1654	3	0.1751
4	0.1543	4	0.1642
5	0.1517	5	0.1657
6	0.1431	6	0.1635
7	0.1571	7	0.1706
8	0.1635	8	0.1613
9	0.1569	9	0.1534
10	0.1607	10	0.1642
Average	0.1541	....	0.1640

Uniformity in size of vein islets in each vine

Schuster and von Zalenski both treated the length of veinlets as a relatively constant character for each plant and even for each species. Most of their work was done with herbaceous annuals, or with a relatively few garden shrubs or trees which may well have been of nearly uniform age. Unless all the leaves of an individual plant show vein islets of relatively equal size, this character cannot be used as a criterion of the age of the vine. In table 5 are shown conditions regarding uniformity of *Vitis vulpina*. The average in each case is of ten or more leaves from each vine.

TABLE 5. UNIFORMITY IN SIZE OF VEIN ISLETS IN EACH VINE

Number of vine	Minimum area of islets (square millimeters)	Average area (square millimeters)	Maximum area (square millimeters)
1	0.1843	0.2039	0.2175
2	0.3581	0.3684	0.3980
3	0.5001	0.5188	0.5288
4	0.2598	0.2700	0.2958

TABLE 5 (*concluded*)

Number of vine	Minimum area of islets (square millimeters)	Average area (square millimeters)	Maximum area (square millimeters)
31	0.3208	0.3337	0.3632
5	0.2819	0.2902	0.3129
6	0.1690	0.1807	0.1910
7	0.1221	0.1375	0.1634
8	0.2698	0.3250	0.3644
9	0.3170	0.3301	0.3453
10	0.2110	0.2291	0.2623
32	0.3500	0.4046	0.4400
33	0.2041	0.2312	0.2909
34	0.2961	0.3045	0.3178
35	0.3000	0.3140	0.3313
36	0.3810	0.3926	0.4061
37	0.4610	0.4743	0.4881
38	0.3097	0.3195	0.3309
39	0.2901	0.3077	0.3205
40	0.2593	0.2823	0.3001
41	0.1376	0.1541	0.1654
11	0.1534	0.1640	0.1751
12	0.3510	0.3946	0.4363
13	0.3489	0.3987	0.4511
15	0.3790	0.4657	0.5018
14	0.2598	0.2965	0.3321
16	0.3098	0.3280	0.3507
18	0.2106	0.2345	0.2511
17	0.4096	0.4845	0.5085
19	0.4597	0.5055	0.5410
21	0.3325	0.3690	0.3889
20	0.2217	0.2503	0.3053
22	0.3017	0.3311	0.3818
23	0.4885	0.5005	0.5171
24	0.3173	0.3553	0.3807
30	0.1337	0.1731	0.2311
Average	0.2961	0.3229	0.3496

The leaves with the smallest vein islets thus show sizes of islets 8.3 per cent below the average for the entire plant, while those with the largest show sizes of islets 8.3 per cent above the average. The degree of variation is distinctly less than that shown by the areas and weights of the leaves themselves, and is not greater than that commonly found in the numerical characters accepted in taxonomic work. This seems to indicate beyond

reasonable doubt that the size of the vein islets is governed by some internal characteristic of the plant as a whole.

The way seems clear, therefore, to investigate the size of the vein islets as a possible indication of the age of the whole plant.

COMPARISON OF THE SIZE OF VEIN ISLETS IN PLANTS OF DIFFERENT AGES, IN VITIS VULPINA

For the purpose of determining whether the size of the vein islets of *Vitis vulpina* is dependent on the age of the whole plant, two methods of comparison were used: (1) a comparison of the size of vein islets in the leaves of these paired vines of different ages which were found growing under nearly identical external conditions; (2) a comparison of the size of the vein islets in the leaves borne by cuttings of vines of different ages which were grown under identical conditions in soil, in nutrient solutions, and in distilled water.

In addition to *Vitis vulpina*, *Vitis bicolor* Le Conte and a number of trees were investigated to a limited extent in regard to a possible relation between venation and age. The data on these latter are presented subsequently.

Size of vein islets of plants grown under field conditions

In the following tables (from table 6 to table 20) there are presented data on the vein islet measurements for each of ten leaves of each paired vine. In each table the average of the vein islet measurements for each of the paired vines is also given. The areas and weights of each leaf are shown. The age of the vine is indicated by the diameter of the main stem and by the number of annual rings.

TABLE 6. AREA OF VEIN ISLETS IN LEAVES OF VINES 1 AND 2

Number of leaf	Length (centimeters)	Breadth (centimeters)	Area (square centimeters)	Weight (grams)	Area of islets (square millimeters)
Vine 1, 7.6 centimeters in diameter, 28 annual rings					
1	13	16	151	2.5	0.2013
2	14	15	140	2.1	0.2112
3	15	19	207	3.6	0.2157
4	15	16	161	3.1	0.2050

TABLE 6 (*concluded*)

Number of leaf	Length (centimeters)	Breadth (centimeters)	Area (square centimeters)	Weight (grams)	Area of islets (square millimeters)
Vine 1, 7.6 centimeters in diameter, 28 annual rings (*concluded*)					
5	14	16	158	2.3	0.2171
6	16	16	178	2.8	0.1843
7	16	19	208	4.0	0.2028
8	15	17	175	3.2	0.2048
9	13	13	118	1.8	0.1941
10	13	15	130	3.2	0.2035
Vine 2, 2 centimeters in diameter, 6 annual rings					
1	13	15	138	2.3	0.3980
2	14	14	138	2.0	0.3716
3	13	15	137	2.2	0.3613
4	11	12	92	1.5	0.3581
5	13	14	124	2.0	0.3637
6	12	11	88	1.3	0.3696
7	12	14	118	1.9	0.3677
8	10	11	77	1.3	0.3691
9	10	11	74	1.2	0.3580
10	13	13	118	1.8	0.3670

Average area of islets for vine with 28 rings.................... 0.2040 square millimeter
Average area of islets for vine with 6 rings...................... 0.3684 square millimeter

TABLE 7. AREA OF VEIN ISLETS IN LEAVES OF VINES 3 AND 4

Number of leaf	Length (centimeters)	Breadth (centimeters)	Area (square centimeters)	Weight (grams)	Area of islets (square millimeters)
Vine 3, 0.7 centimeter in diameter, 3 annual rings					
1	15	17	190	2.3	0.5277
2	14	13	127	1.5	0.5151
3	17	18	210	2.2	0.5100
4	15	16	162	1.6	0.5180
5	15	16	162	1.7	0.5151
6	15	15	157	1.6	0.5288
7	14	16	152	1.8	0.5264
8	14	13	147	1.6	0.5001
9	15	17	173	2.0	0.5120
10	14	15	147	1.5	0.5010

TABLE 7 (*concluded*)

Number of leaf	Length (centimeters)	Breadth (centimeters)	Area (square centimeters)	Weight (grams)	Area of islets (square millimeters)
Vine 4, 7.6 centimeters in diameter, 25 annual rings					
1	12	15	116	1.9	0.2958
2	13	16	146	1.9	0.2598
3	14	14	133	1.7	0.2641
4	14	16	155	1.9	0.2698
5	12	14	119	1.3	0.2684
6	12	13	105	1.4	0.2710
7	10	12	84	1.0	0.2675
8	8	10	52	1.0	0.2720
9	9	10	63	1.0	0.2600
10	12	15	126	1.6	0.2640

Average area of islets for vine with 3 rings.................... 0.5154 square millimeter
Average area of islets for vine with 25 rings.................. 0.2692 square millimeter

TABLE 8. AREA OF VEIN ISLETS IN LEAVES OF VINES 5 AND 6

Number of leaf	Length (centimeters)	Breadth (centimeters)	Area (square centimeters)	Weight (grams)	Area of islets (square millimeters)
Vine 5, 5.1 centimeters in diameter, 22 annual rings					
1	12	13	109	1.6	0.2813
2	12	15	126	1.6	0.2876
3	10	12	80	1.3	0.3129
4	8	13	72	1.8	0.2930
5	11	15	133	1.5	0.2818
6	13	15	140	1.8	0.2820
7	10	13	85	1.3	0.2912
8	13	11	97	1.4	0.2872
9	14	14	130	1.6	0.2953
10	14	16	152	1.8	0.2890
Vine 6, 20.4 centimeters in diameter, 56 annual rings					
1	11	11	85	0.8	0.1830
2	13	13	118	1.5	0.1910
3	14	14	132	1.4	0.1750
4	13	14	125	1.5	0.1810
5	10	11	74	0.7	0.1910
6	12	11	92	1.0	0.1756
7	11	12	92	0.9	0.1841

TABLE 8 (*concluded*)

Number of leaf	Length (centimeters)	Breadth (centimeters)	Area (square centimeters)	Weight (grams)	Area of islets (square millimeters)
Vine 6, 20.4 centimeters in diameter, 56 annual rings (*concluded*)					
8	12	11	85	1.0	0.1764
9	12	14	112	1.4	0.1690
10	13	13	110	1.2	0.1814

Average area of islets for vine with 22 rings.................... 0.2901 square millimeter
Average area of islets for vine with 56 rings.................... 0.1807 square millimeter

TABLE 9. AREA OF VEIN ISLETS IN LEAVES OF VINES 7 AND 8

Number of leaf	Length (centimeters)	Breadth (centimeters)	Area (square centimeters)	Weight (grams)	Area of islets (square millimeters)
Vine 7, 15.3 centimeters in diameter, 70 annual rings					
1	10	12	84	0.9	0.1335
2	12	14	117	0.9	0.1634
3	10	11	74	0.4	0.1238
4	9	10	60	0.3	0.1574
5	10	12	80	0.4	0.1221
6	10	11	77	0.5	0.1310
7	11	11	85	0.5	0.1360
8	10	11	74	0.4	0.1280
9	12	14	115	0.9	0.1412
10	13	14	120	0.8	0.1392
Vine 8, 3.2 centimeters in diameter, 15 annual rings					
1	10	10	70	0.6	0.2866
2	10	11	74	0.6	0.2698
3	11	12	89	0.7	0.3644
4	13	12	109	0.8	0.3525
5	9	9	57	0.4	0.3166
6	11	11	87	0.6	0.3270
7	11	12	90	0.6	0.3460
8	11	11	80	0.7	0.3272
9	8	9	46	0.4	0.3360
10	9	9	57	0.5	0.3241

Average area of islets for vine with 70 rings.................... 0.1376 square millimeter
Average area of islets for vine with 15 rings.................... 0.3250 square millimeter

TABLE 10. AREA OF VEIN ISLETS IN LEAVES OF VINES 9 AND 10

Number of leaf	Length (centimeters)	Breadth (centimeters)	Area (square centimeters)	Weight (grams)	Area of islets (square millimeters)
Vine 9, 3.3 centimeters in diameter, 14 annual rings					
1	14	15	140	1.5	0.3390
2	14	15	147	1.6	0.3453
3	13	13	112	1.2	0.3292
4	14	14	140	1.4	0.3390
5	11	11	85	0.8	0.3355
6	12	11	90	0.8	0.3240
7	10	12	84	0.7	0.3172
8	15	18	182	2.0	0.3361
9	14	12	118	1.2	0.3170
10	11	13	100	0.8	0.3211
Vine 10, 7.6 centimeters in diameter, 30 annual rings					
1	10	11	77	0.6	0.2141
2	10	10	70	0.7	0.2623
3	14	12	112	1.7	0.2460
4	15	17	170	2.4	0.2350
5	15	15	154	1.8	0.2228
6	11	12	87	0.7	0.2241
7	14	15	147	1.8	0.2342
8	15	16	162	2.0	0.2110
9	15	15	158	1.9	0.2151
10	11	13	90	0.9	0.2262

Average area of islets for vine with 14 rings.................. 0.3303 square millimeter
Average area of islets for vine with 30 rings.................. 0.2291 square millimeter

TABLE 11. AREA OF VEIN ISLETS IN LEAVES OF VINES 11 AND 12

Number of leaf	Length (centimeters)	Breadth (centimeters)	Area (square centimeters)	Weight (grams)	Area of islets (square millimeters)
Vine 11, 1.3 centimeters in diameter, 6 annual rings (only nine leaves picked)					
1	14	12	110	1.3	0.3617
2	17	15	170	2.0	0.4246
3	17	14	155	1.7	0.4363
4	17	16	180	2.1	0.3510
5	15	13	130	1.5	0.3571

TABLE 11 (*concluded*)

Number of leaf	Length (centimeters)	Breadth (centimeters)	Area (square centimeters)	Weight (grams)	Area of islets (square millimeters)
Vine 11, 1.3 centimeters in diameter, 6 annual rings (only nine leaves picked) (*concluded*)					
6	15	13	140	1.6	0.4006
7	14	11	98	1.0	0.4213
8	17	16	190	2.2	0.4313
9	15	12	126	1.4	0.3679
Vine 12, 15.3 centimeters in diameter, 57 annual rings					
1	9	10	60	0.8	0.1543
2	9	9	54	0.7	0.1678
3	10	10	66	0.7	0.1751
4	10	10	73	0.9	0.1642
5	9	8	48	0.6	0.1657
6	9	10	60	0.7	0.1635
7	8	7	40	0.5	0.1706
8	10	9	63	0.7	0.1613
9	8	8	41	0.4	0.1534
10	8	7	40	0.5	0.1642

Average area of islets for vine with 6 rings.................. 0.3946 square millimeter
Average area of islets for vine with 57 rings.................. 0.1640 square millimeter

TABLE 12. AREA OF VEIN ISLETS IN LEAVES OF VINES 13 AND 14

Number of leaf	Length (centimeters)	Breadth (centimeters)	Area (square centimeters)	Weight (grams)	Area of islets (square millimeters)
Vine 13, 1.3 centimeters in diameter, 6 annual rings (only five leaves picked)					
1	13	12	109	1.2	0.3597
2	15	10	108	1.1	0.4213
3	12	10	84	0.9	0.3489
4	10	9	65	0.7	0.4106
5	8	5	30	0.4	0.4511
Vine 14, 5.1 centimeters in diameter, 16 annual rings					
1	16	16	180	2.1	0.3209
2	10	10	70	0.9	0.2871
3	13	12	110	1.2	0.2696
4	13	13	112	1.2	0.3213

TABLE 12 (*concluded*)

Number of leaf	Length (centimeters)	Breadth (centimeters)	Area (square centimeters)	Weight (grams)	Area of islets (square millimeters)
Vine 14, 5.1 centimeters in diameter, 16 annual rings (*concluded*)					
5	12	12	100	1.0	0.2871
6	14	15	150	1.7	0.3107
7	18	16	210	2.3	0.2879
8	12	12	106	1.1	0.3321
9	14	15	145	1.6	0.2897
10	14	14	135	1.5	0.2598

Average area of islets for vine with 6 rings.................. 0.3983 square millimeter
Average area of islets for vine with 16 rings.................. 0.2966 square millimeter

TABLE 13. AREA OF VEIN ISLETS IN LEAVES OF VINES 15 AND 16

Number of leaf	Length (centimeters)	Breadth (centimeters)	Area (square centimeters)	Weight (grams)	Area of islets (square millimeters)
Vine 15, 0.8 centimeter in diameter, 5 annual rings (only five leaves picked)					
1	10	9	60	0.6	0.3790
2	9	8	54	0.6	0.5013
3	10	10	73	0.8	0.4678
4	11	9	70	0.8	0.5018
5	12	10	84	0.9	0.4787
Vine 16, 5.1 centimeters in diameter, 14 annual rings					
1	14	13	135	1.5	0.3312
2	14	15	145	1.6	0.3176
3	13	11	105	1.2	0.3098
4	14	16	150	1.7	0.3421
5	15	14	150	1.6	0.3507
6	12	13	110	1.2	0.3312
7	14	14	135	1.5	0.3212
8	13	12	107	1.1	0.3106
9	12	12	106	1.1	0.3361
10	13	12	110	1.2	0.3301

Average area of islets for vine with 5 rings.................. 0.4657 square millimeter
Average area of islets for vine with 14 rings.................. 0.3281 square millimeter

TABLE 14. AREA OF VEIN ISLETS IN LEAVES OF VINES 17 AND 18

Number of leaf	Length (centimeters)	Breadth (centimeters)	Area (square centimeters)	Weight (grams)	Area of islets (square millimeters)
Vine 17, 1.3 centimeters in diameter, 5 annual rings (only eight leaves picked)					
1	12	11	90	0.9	0.4863
2	12	12	100	1.1	0.5017
3	12	10	78	0.9	0.4096
4	12	13	104	1.1	0.5023
5	12	10	80	0.9	0.5085
6	11	12	85	0.9	0.4893
7	10	10	75	0.8	0.4971
8	11	10	75	0.9	0.4813
Vine 18, 10.1 centimeters in diameter, 35 annual rings					
1	14	15	150	1.7	0.2417
2	14	13	130	1.4	0.2378
3	15	14	135	1.5	0.2363
4	14	14	125	1.4	0.2419
5	13	13	115	1.3	0.2263
6	13	12	110	1.2	0.2511
7	11	14	110	1.3	0.2387
8	12	11	90	1.0	0.2267
9	11	13	100	1.1	0.2239
10	10	13	90	1.0	0.2106

Average area of islets for vine with 5 rings.................. 0.4845 square millimeter
Average area of islets for vine with 35 rings.................. 0.2335 square millimeter

TABLE 15. AREA OF VEIN ISLETS IN LEAVES OF VINES 19 AND 20

Number of leaf	Length (centimeters)	Breadth (centimeters)	Area (square centimeters)	Weight (grams)	Area of islets (square millimeters)
Vine 19, 1.5 centimeters in diameter, 5 annual rings					
1	15	13	110	1.2	0.5410
2	13	12	105	1.1	0.5363
3	14	13	140	1.6	0.4597
4	13	12	115	1.2	0.4817
5	15	13	135	1.6	0.4861
6	16	15	170	1.9	0.4877
7	14	13	125	1.4	0.5437
8	13	13	120	1.4	0.5019
9	12	12	105	1.3	0.5115
10	11	12	100	1.2	0.5061

TABLE 15 (*concluded*)

Number of leaf	Length (centimeters)	Breadth (centimeters)	Area (square centimeters)	Weight (grams)	Area of islets (square millimeters)
Vine 20, 10.1 centimeters in diameter, 25 annual rings					
1	8	7	38	0.5	0.2509
2	8	8	45	0.6	0.2263
3	9	7	50	0.6	0.2217
4	9	11	65	0.7	0.3053
5	11	10	75	0.8	0.2506
6	8	9	65	0.8	0.2618
7	7	7	45	0.6	0.2791
8	11	12	85	1.0	0.2507
9	11	10	85	0.9	0.2273
10	10	10	75	0.9	0.2291

Average area of islets for vine with 5 rings .... 0.5056 square millimeter
Average area of islets for vine with 25 rings .... 0.2503 square millimeter

TABLE 16. AREA OF VEIN ISLETS IN LEAVES OF VINES 21 AND 22

Number of leaf	Length (centimeters)	Breadth (centimeters)	Area (square centimeters)	Weight (grams)	Area of islets (square millimeters)
Vine 21, 2.5 centimeters in diameter, 11 annual rings					
1	13	14	125	1.4	0.3191
2	11	12	90	1.0	0.3889
3	13	14	120	1.3	0.3325
4	12	12	140	1.6	0.3835
5	12	13	110	1.2	0.3896
6	12	14	120	1.4	0.3764
7	10	12	95	1.1	0.3761
8	13	13	100	1.2	0.3673
9	10	11	80	0.9	0.3809
10	10	11	85	0.9	0.3761
Vine 22, 5.1 centimeters in diameter, 17 annual rings					
1	17	17	202	2.2	0.3087
2	17	18	216	2.4	0.3818
3	15	15	158	1.8	0.3506
4	14	14	135	1.5	0.3017
5	15	15	160	1.8	0.3063
6	15	14	150	1.7	0.3219

TABLE 16 (*concluded*)

Number of leaf	Length (centimeters)	Breadth (centimeters)	Area (square centimeters)	Weight (grams)	Area of islets (square millimeters)
Vine 22, 5.1 centimeters in diameter, 17 annual rings (*concluded*)					
7	15	14	145	1.6	0.3367
8	15	15	160	1.8	0.3503
9	15	15	165	1.9	0.3307
10	14	14	130	1.5	0.3218

Average area of islets for vine with 11 rings.................. 0.3690 square millimeter
Average area of islets for vine with 17 rings.................. 0.3310 square millimeter

TABLE 17. AREA OF VEIN ISLETS IN LEAVES OF VINES 23 AND 24

Number of leaf	Length (centimeters)	Breadth (centimeters)	Area (square centimeters)	Weight (grams)	Area of islets (square millimeters)
Vine 23, 0.8 centimeter in diameter, 5 annual rings (only nine leaves picked)					
1	11	11	80	0.9	0.4893
2	12	10	80	0.9	0.4972
3	10	12	85	0.9	0.4885
4	11	11	85	0.9	0.5006
5	10	12	90	1.0	0.5097
6	10	11	70	0.8	0.4998
7	9	9	60	0.7	0.5013
8	9	7	50	0.6	0.5171
9	10	11	75	0.8	0.4909
Vine 24, 2.5 centimeters in diameter, 10 annual rings					
1	12	11	100	1.1	0.3709
2	10	11	75	0.9	0.3761
3	12	13	115	1.3	0.3781
4	11	12	101	1.1	0.3407
5	10	11	70	0.8	0.3173
6	10	11	75	0.9	0.3164
7	10	11	80	0.9	0.3187
8	11	13	95	1.0	0.3861
9	11	12	95	1.0	0.3275
10	11	12	100	1.1	0.3209

Average area of islets for vine with 5 rings.................... 0.4994 square millimeter
Average area of islets for vine with 10 rings.................... 0.3453 square millimeter

TABLE 18. AREA OF VEIN ISLETS IN LEAVES OF VINES 25 AND 26

Number of leaf	Length (centimeters)	Breadth (centimeters)	Area (square centimeters)	Weight (grams)	Area of islets (square millimeters)
Vine 25, 3 centimeters in diameter, 11 annual rings (only five leaves photographed)					
1	13	14	125	1.4	0.3761
2	14	13	130	1.5	0.3506
3	14	15	145	1.6	0.3391
4	13	15	135	1.5	0.3476
5	12	13	100	1.1	0.3736
Vine 26, 12.7 centimeters in diameter, 35 annual rings (only five leaves photographed)					
1	12	11	90	1.0	0.2216
2	13	13	100	1.1	0.2035
3	14	15	150	1.7	0.2107
4	11	13	100	1.1	0.2316
5	12	13	110	1.2	0.2217

Average area of islets for vine with 11 rings .... 0.3574 square millimeter
Average area of islets for vine with 35 rings .... 0.2178 square millimeter

TABLE 19. AREA OF VEIN ISLETS IN LEAVES OF VINES 27 AND 28

Number of leaf	Length (centimeters)	Breadth (centimeters)	Area (square centimeters)	Weight (grams)	Area of islets (square millimeters)
Vine 27, 5.1 centimeters in diameter, 17 annual rings (only five leaves photographed)					
1	15	15	150	1.7	0.3281
2	13	12	110	1.3	0.3011
3	16	15	165	1.8	0.3132
4	13	13	110	1.3	0.3313
5	13	13	115	1.2	0.3063
Vine 28, 7.6 centimeters in diameter, 25 annual rings (only five leaves photographed)					
1	11	11	85	0.9	0.2261
2	12	11	90	1.0	0.2306
3	14	13	125	1.4	0.2413
4	13	10	100	1.1	0.2371
5	15	13	125	1.4	0.2283

Average area of islets for vine with 17 rings .... 0.3160 square millimeter
Average area of islets for vine with 25 rings .... 0.2327 square millimeter

TABLE 20. AREA OF VEIN ISLETS IN LEAVES OF VINES 29 AND 30

Number of leaf	Length (centimeters)	Breadth (centimeters)	Area (square centimeters)	Weight (grams)	Area of islets (square millimeters)
Vine 29, 2.5 centimeters in diameter, 10 annual rings (only five leaves photographed)					
1	11	12	90	1.1	0.3613
2	14	15	145	1.6	0.3725
3	13	13	115	1.3	0.3617
4	15	14	135	1.5	0.3867
5	16	15	155	1.7	0.3975
Vine 30, 12.7 centimeters in diameter, 50 annual rings					
1	8	7	42	0.5	0.2013
2	8	8	50	0.6	0.1809
3	8	6	40	0.5	0.2311
4	8	7	45	0.6	0.2263
5	10	10	70	0.8	0.1491
6	9	9	60	0.7	0.1347
7	9	10	64	0.7	0.1509
8	9	9	62	0.7	0.1814
9	10	10	70	0.8	0.1337
10	10	9	60	0.7	0.1416

Average area of islets for vine with 10 rings.................... 0.3759 square millimeter
Average area of islets for vine with 50 rings.................... 0.1731 square millimeter

TABLE 21. SUMMARY OF RELATION FOUND BETWEEN AGE OF VINE OF VITIS VULPINA AND AREA OF VEIN ISLETS IN THE LEAVES

Number of vine	Number of annual rings	Area of islets (square millimeters)	Number of vine	Number of annual rings	Area of islets (square millimeters)
3	3	0.5154	14	16	0.2966
19	5	0.5056	27	17	0.3160
23	5	0.4994	22	17	0.3310
17	5	0.4845	5	22	0.2901
15	5	0.4657	4	25	0.2692
13	6	0.3983	20	25	0.2503
11	6	0.3946	28	25	0.2327
2	6	0.3684	1	28	0.2040
29	10	0.3759	10	30	0.2291
24	10	0.3453	18	35	0.2335
21	11	0.3690	26	35	0.2178
25	11	0.3574	30	50	0.1731
9	14	0.3303	6	56	0.1807
16	14	0.3281	12	57	0.1640
8	15	0.3250	7	70	0.1376

FIG. 55.—*Curve showing decrease with age in size of vein islets of leaves of Vitis vulpina*

By averaging the size of the vein islets in vines of the same age, a curve can be plotted which shows very strikingly the decrease in the size of the islets with increasing age. Such a curve is shown in figure 55.

When the plants in the above summary are divided into groups the change in venation is even more apparent, as shown in table 22.

In figure 56 are shown photographs of the venation characteristic of each of these groups.

TABLE 22. AVERAGE AREA OF VEIN ISLETS IN LEAVES OF VINES GROUPED ACCORDING TO AGE

Number of rings	3 to 5	6 to 11	14 to 25	28 to 35	50 to 70
Area of vein islets (square millimeters)	0.4941	0.3727	0.2969	0.2211	0.1638

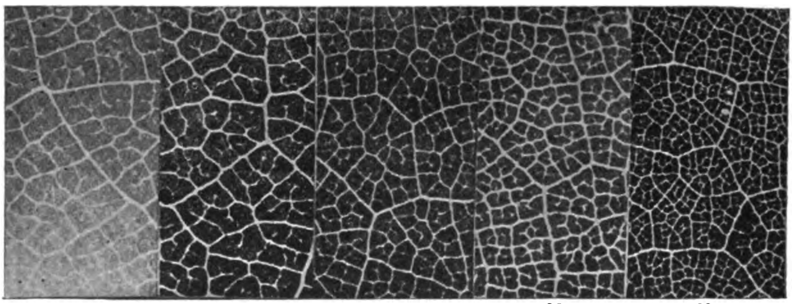

FIG. 56.—*Photographs of vein islets of leaves of Vitis vulpina vines of the ages of 3, 6, 14, 28, and 60 years, grown under identical conditions*

Size of islets in leaves of cuttings grown under identical conditions

In order to test further the constancy of the different sizes of vein islets found, cuttings were made, in three different summers, from the

various vines studied. These cuttings were grown in water and in soil cultures, and the leaves that developed were measured and studied. The cuttings were classified into groups according to the age of the vine from which they were taken, and were labeled accordingly but grown together under identical conditions.

Of the first series of cuttings grown in tap water, seventeen proved successful. They were grown in a greenhouse at Ithaca. Since it was necessary for the writer to go to Cincinnati at the close of the summer, the measurements of the vein islets were made before the leaves had attained maturity. The results of these measurements are given in table 23. The number of rings as given in the table indicates the age of the vine from which the cuttings were made; the size given for the vein islets is the average for all the leaves of one cutting.

TABLE 23. AREA OF VEIN ISLETS IN LEAVES FROM CUTTINGS GROWN IN TAP WATER

	Number of rings			
	4 to 5	7 to 11	14 to 16	25 to 50
	(Square millimeters)	(Square millimeters)	(Square millimeters)	(Square millimeters)
	0.24	0.20	0.16	0.14
	0.26	0.21	0.22	0.15
	0.29	0.22	0.17	0.15
	0.30	0.23	0.18	0.15
	....	0.32	....	....
Average.....	0.27	0.24	0.18	0.15

The vein islets are noticeably smaller than those in leaves grown under natural conditions, and this is due to the fact that the leaves were not fully expanded. The smaller the leaf, the smaller are the islets until the maturity of the leaf is reached. These differences in size of vein islets of leaves of old and of young vines are obvious at the time when the leaf buds first open, and are maintained throughout the later stages of leaf growth, as is shown by tables 24 and 25, pages 312 and 313.

Comparison of the venation of immature leaves

In order to determine whether or not the difference in size of vein islets is present from the beginning of the development of the leaf, the venation of a series of leaves from the tips of shoots backward was examined. One examination was made by the photographic method, with the following results:

TABLE 24. AREA OF VEIN ISLETS IN A SERIES OF IMMATURE LEAVES TAKEN IN ORDER FROM THE TIPS OF THE SHOOTS BACKWARD, FROM VITIS VULPINA TWENTY-FIVE AND TEN YEARS OF AGE

Number of leaf	Length (centimeters)	Breadth (centimeters)	Weight (grams)	Area of vein islets (square millimeters)
		Vine twenty-five years old		
1	3	3	0.15	0.010
2	5	4	0.30	0.015
3	7	6	0.50	0.022
4	8	9	0.60	0.058
5	11	10	0.95	0.090
6	11	12	1.10	0.120
7	14	17	2.10	0.150
8	13	14	1.90	0.190
		Vine ten years old		
1	3	3	0.16	0.015
2	6	5	0.29	0.020
3	8	6	0.51	0.027
4	9	8	0.63	0.065
5	10	11	1.00	0.098
6	11	12	1.20	0.150
7	14	17	2.20	0.200
8	13	14	2.00	0.260

That this was an entirely typical condition has been shown by many field counts of veinlet intersections by a method explained later (page 315). The sizes of the vein islets in the immature leaves on the cuttings as given in table 23 offer evidence to the same effect.

If the midrib be called the primary vein, its chief branches secondary veins, the main branches of the secondary veins tertiary, and so on, the final most minute veinlets may be given a definite rank. A comparison

of the rank of the veinlets in leaves borne by cuttings of *Vitis vulpina* of different ages shows the following results:

TABLE 25. RANK OF VEINLETS IN IMMATURE LEAVES BORNE BY CUTTINGS OF VITIS VULPINA OF DIFFERENT AGES

Position of leaf	Enclosing veinlets	Penetrating veinlets
Vine twelve years old		
First leaf on cuttings	5th rank	6th rank
Second leaf	6th rank	7th rank
Third leaf	6th rank	7th rank
Fourth leaf	6th rank	7th rank
Fifth leaf	7th rank	8th rank
Sixth leaf	7th rank	8th rank
Seventh leaf	7th rank	8th rank
Vine twenty-six years old		
First leaf	6th rank	7th rank
Second leaf	7th rank	8th rank
Third leaf	6th rank	7th rank
Fourth leaf	7th rank	7th rank
Fifth leaf	7th rank	8th rank
Sixth leaf	8th rank	9th rank
Seventh leaf	8th rank	9th rank

The important fact is evident from table 25 that in the leaf from the older vine the vein islets have been divided by the development of an additional rank of veinlets, and each division has been partly penetrated by veinlets of still higher rank. The fact that size relationship of the vein islets holds for the immature leaves of old and young vines as definitely as it does for the mature ones, which have been subjected to the various external factors of environment, is further evidence of importance supporting the claim that the difference in size of the vein islets is due to a constitutional rather than to an environmental cause.

In May, 1910, another set of cuttings was started, this time in prepared soil. These cuttings were obtained and started for the writer by an assistant, and the grouping was somewhat different from that used in the first series. All the cuttings were grown in the same box of prepared soil and all environmental conditions were identical for

each cutting. The cuttings produced mature leaves in time for study during the summer. The average size of the vein islets in the leaves of each of these fifty-four cuttings is shown in table 26, the number of rings indicating the age in years of the vine from which the cuttings were made. The cuttings themselves varied in diameter from 1.3 to 2.5 centimeters, both small and large cuttings being taken from the older vines. The size of the vein islets had no relation to the size of the cuttings.

TABLE 26. AREA OF VEIN ISLETS IN LEAVES FROM CUTTINGS GROWN IN SOIL

	Number of rings		
	5 to 15	16 to 25	26 to 40
	(Square millimeters)	(Square millimeters)	(Square millimeters)
	0.52	0.37	0.32
	0.50	0.37	0.33
	0.49	0.35	0.28
	0.41	0.34	0.30
	0.40	0.35	0.36
	0.36	0.35	0.38
	0.34	0.30	0.38
	0.36	0.37	0.34
	0.44	0.34	0.40
	0.40	0.40	0.32
	0.50	....	0.35
	0.49	....	0.31
	0.49	....	0.23
	0.48	....	0.26
	0.48	....	0.26
	0.47	....	0.33
	0.42	....	0.33
	0.40	....	0.23
	0.42	....	0.23
	0.36	....	0.20
	....	....	0.23
	....	....	0.24
	....	....	0.23
	....	....	0.23
Average........	0.44	0.35	0.29

The relation between the size of vein islets in these cuttings and the age of the original vines is graphically shown in curve A of figure 57.

It is possible that many of the cuttings came from vines on the boundary lines of the age groups, instead of being evenly distributed throughout the whole range of each group; but, in spite of this, the inherent effect of the age of the vine is plainly seen.

METHOD FOR DETERMINING APPROXIMATE AGE BY MEASUREMENT OF VEINAGE

In addition to the foregoing investigation, hundreds of field measurements of the relation between the size of islets and the age of the vine were made, in five different summers, about Cincinnati and Ithaca. The method used was simple, and well adapted to the practical nurseryman and fruit grower. A paper clip (called the cub tiger clip) was procured and a distance of two centimeters marked along the jaws. A piece of the leaf to be examined was torn out from between two large secondary veins, held by the clip toward the light, and examined with a pocket lens. The number of veinlets intersecting the edge of the jaw in a distance of two centimeters was counted in several places on the leaf and the average was taken. The result of these observations showed that such an average gives a rough approximation of the age of the vine on which leaves have grown, as indicated in table 27:

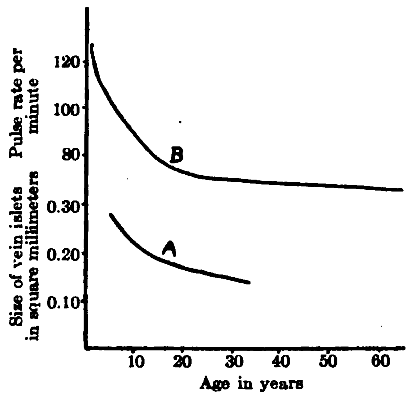

FIG. 57.— *Curves showing (A) senile decrease in size of vein islets in leaves borne by cuttings of Vitis vulpina, and (B) senile decrease in pulse rate in human beings*

TABLE 27. FIELD METHOD OF DETERMINING THE APPROXIMATE AGE OF VITIS VULPINA VINES FROM THE SIZE OF THE VEIN ISLETS IN THE LEAVES

Number of veinlets intersecting a straight line in two centimeters	Corresponding age of vine
30 to 35	5 years or less
35 to 45	5 to 15 years
45 to 50	15 to 35 years
50 to 75	35 years and upward

While this method is, of course, not so free from error as the photographic method — since only a fraction of the actual number of islets are measured and a lineal instead of an area calculation is employed — still it is a practical method for general use in field, nursery, and orchard, such as was originally sought.

In about one per cent of the several hundred field determinations made and checked by ring counts, serious discrepancies were found. It is possible that these exceptional vines were examples of such extreme variations as are sometimes found in other specific morphological characters. A number of other species of perennial plants were examined, and it was found that, while the size of vein islets always diminished with age, the actual size of the islets at any age was a specific character relatively constant in each species. Such individual abnormal plants as those mentioned above resemble other species in the character of their venation.

COMPARISON OF SIZE OF VEIN ISLETS IN PLANTS OF DIFFERENT AGES, IN VITIS BICOLOR AND CERTAIN OTHER PLANTS

The results of a preliminary investigation of the relation between age and venation in some woody perennials other than *Vitis vulpina* are given in the following pages.

Size of vein islets in Vitis bicolor Le Conte

The vines used for these measurements were not transversely cut, and the only guide that could be obtained to their relative ages was the diameter of the stems. They were all growing in the same small area, under apparently identical conditions.

TABLE 28. AREA OF VEIN ISLETS IN LEAVES OF VITIS BICOLOR, VINES 1 AND 2

Number of leaf	Length (centimeters)	Breadth (centimeters)	Area (square centimeters)	Weight (grams)	Area of islets (square millimeters)
Vine 1, 25.5 centimeters in diameter					
1	17	18	200	2.0	0.2276
2	18	17	210	2.7	0.2298
3	16	15	170	2.6	0.2909
4	18	18	220	3.5	0.2391

TABLE 28 (*concluded*)

Number of leaf	Length (centimeters)	Breadth (centimeters)	Area (square centimeters)	Weight (grams)	Area of islets (square millimeters)
	Vine 1, 25.5 centimeters in diameter (*concluded*)				
5	18	17	220	2.8	0.2256
6	14	15	147	2.0	0.2127
7	17	18	210	2.8	0.2041
8	17	20	230	3.4	0.2113
9	14	17	170	2.6	0.2418
10	19	19	260	2.6	0.2291
	Vine 2, 3.8 centimeters in diameter				
1	13	15	140	2.1	0.3810
2	12	13	105	1.5	0.4061
3	13	15	135	2.2	0.3818
4	15	15	155	2.2	0.3819
5	13	14	125	2.1	0.4021
6	10	13	90	1.1	0.3971
7	14	15	145	2.1	0.3818
8	12	12	100	1.2	0.3981
9	11	12	85	1.0	0.4001
10	12	13	105	1.5	0.3961

Average area of islets for vine 25.5 centimeters in diameter...... 0.2312 square millimeter
Average area of islets for vine 3.8 centimeters in diameter....... 0.3926 square millimeter

TABLE 29. AREA OF VEIN ISLETS IN LEAVES OF VITIS BICOLOR, VINES 3 AND 4

Number of leaf	Length (centimeters)	Breadth (centimeters)	Area (square centimeters)	Weight (grams)	Area of islets (square millimeters)
	Vine 3, 15.3 centimeters in diameter				
1	12	18	160	3.0	0.3066
2	13	17	165	3.0	0.3170
3	14	15	150	2.9	0.3001
4	13	17	165	3.0	0.3101
5	13	14	115	2.6	0.2909
6	13	16	145	2.5	0.2961
7	12	16	120	2.7	0.3106
8	14	15	145	3.1	0.2989
9	13	16	150	2.9	0.3179
10	13	16	145	2.8	0.3091

TABLE 29 (*concluded*)

Number of leaf	Length (centimeters)	Breadth (centimeters)	Area (square centimeters)	Weight (grams)	Area of islets (square millimeters)
		Vine 4, 2.5 centimeters in diameter			
1	14	16	160	2.2	0.4687
2	13	16	155	2.5	0.4865
3	13	16	145	2.1	0.4671
4	14	16	160	2.4	0.4881
5	14	12	125	2.0	0.4652
6	15	17	180	2.5	0.4721
7	15	17	185	2.1	0.4863
8	14	17	170	2.6	0.4769
9	13	17	160	2.2	0.4610
10	13	14	115	1.9	0.4713

Average area of islets for vine 15.3 centimeters in diameter...... 0.3057 square millimeter
Average area of islets for vine 2.5 centimeters in diameter........ 0.4743 square millimeter

TABLE 30. AREA OF VEIN ISLETS IN LEAVES OF VITIS BICOLOR, VINES 5 AND 6

Number of leaf	Length (centimeters)	Breadth (centimeters)	Area (square centimeters)	Weight (grams)	Area of islets (square millimeters)
		Vine 5, 20.4 centimeters in diameter			
1	13	16	155	2.4	0.3313
2	14	14	140	1.7	0.3000
3	14	16	160	2.5	0.3001
4	13	15	135	2.2	0.3139
5	12	15	120	2.0	0.3294
6	14	15	145	2.0	0.3012
7	13	16	140	2.4	0.3116
8	14	13	135	1.8	0.3285
9	11	15	120	1.8	0.3017
10	12	14	120	1.4	0.3123
		Vine 6, 4.5 centimeters in diameter			
1	11	14	110	1.3	0.3713
2	10	14	105	1.2	0.2867
3	10	14	100	0.8	0.3873
4	10	12	90	1.2	0.4013
5	12	13	110	1.7	0.3764
6	12	14	115	1.7	0.3971
7	13	14	130	1.9	0.3865
8	13	15	135	2.0	0.3871

TABLE 30 (*concluded*)

Number of leaf	Length (centimeters)	Breadth (centimeters)	Area (square centimeters)	Weight (grams)	Area of islets (square millimeters)
Vine 6, 4.5 centimeters in diameter (*concluded*)					
9	11	16	115	1.8	0.3763
10	13	14	135	0.8	0.3705

Average area of islets for vine 20.4 centimeters in diameter...... 0.3130 square millimeter
Average area of islets for vine 4.5 centimeters in diameter....... 0.3740 square millimeter

TABLE 31. SUMMARY OF DATA FOR VITIS BICOLOR LE CONTE

Diameter of vine (in centimeters)	2.5	3.8	4.5	15.3	20 4	25.5
Size of islets (in square millimeters)	0.4743	0.3926	0.3740	0.3057	0.3130	0.2312

This species is characterized by larger vein islets than those of *Vitis vulpina*, but exhibits the same age-venation relationship.

Size of vein islets in Tecoma radicans L.

The vines of *Tecoma radicans* examined were growing in a private yard. Those that were 20.4 centimeters in diameter had been planted, and the smaller ones had come up from their seeds. The size of islets given is the average for ten leaves of each plant. Here again the vines were not cut and the age must be inferred from the diameter of the stem.

TABLE 32. AREA OF VEIN ISLETS IN TECOMA RADICANS

	Diameter of stem		
	1.3 centimeters	3.8 centimeters	20.4 centimeters
	Square millimeters	Square millimeters	Square millimeters
	1.5	0.95	0.62
	1.4	0.97	0.63
	1.5	0.94	0.68
	1.6	0.98	0.70
	....	0.96	0.67
Average	1.5	0.96	0.66

In this case, as in the case of *Vitis vulpina* and *V. bicolor*, the more rapid decrease in size of vein islets in the early years is to be particularly noted. The significance of this will be discussed later.

Another interesting observation was made with these specimens of *Tecoma radicans*. Among the seedlings that sprouted around the parent vines, root shoots from the old vines were found growing. The connection of these root shoots was established by examination. Although seedlings and root shoots seemed equally vigorous and could not be distinguished from each other at first sight, a venation count successfully separated them, since the root shoots all showed in their leaves the size of vein islets characteristic of the parent plant, while those of the seedlings were much larger. This fact is of considerable importance in its bearing on the cause of these differences, as will be indicated later.

Size of vein islets in several kinds of trees

The following data, as is evident, represent nothing but a comparison of a few trees of different ages that were growing under similar external conditions, and the results are interesting merely as a corroboration of the effect of age in decreasing the size of vein islets in perennials:

TABLE 33. RELATION OF SIZE OF VEIN ISLETS TO AGE IN SALIX NIGRA MARSH

Diameter of trunk (in centimeters)	2.5	15.3	38.1
Area of islets (in square millimeters)	0.55	0.4	0.3

The largest tree was probably the parent of the others, as they grew in an isolated place.

TABLE 34. RELATION OF SIZE OF VEIN ISLETS TO AGE IN CASTANEA DENTATA BORKH.

Diameter of trunk (in centimeters)	5.1	12.7	25.5	61.2	91.2
Area of islets (in square millimeters)	1.0	0.7	0.5	0.4*	0.3

* The tree 61.2 centimeters in diameter had been cut down, and the leaves examined were very large ones borne on luxuriant water sprouts.

TABLE 35. RELATION OF SIZE OF VEIN ISLETS TO AGE IN QUERCUS ALBA L.

Diameter of trunk (in centimeters)	0.7	40.8	38.0
Area of islets (in square millimeters)	1.5	0.3*	0.3

* The leaves examined were much larger than normal size, being borne on luxuriant water sprouts.

TABLE 36. RELATION OF SIZE OF VEIN ISLETS TO AGE IN TILIA AMERICANA L.

Diameter of trunk (in centimeters)	7.6	35.7
Area of leaf (in square centimeters)	30.0	1,560.0
Area of islets (in square millimeters)	0.04	0.02

In the latter case the leaves were borne by water sprouts growing from the stump and they were fifty times the size of the leaves on the small tree; yet the size of the vein islets corresponded to the age of the plant.

TABLE 37. RELATION OF SIZE OF VEIN ISLETS TO AGE IN ULMUS AMERICANA L.

Diameter of trunk (in centimeters)	30.6	35.7*
Area of islets (in square millimeters)	0.8	0.6

The use of the field method is shown in the following figures obtained from the same species:

Diameter of trunk (in centimeters)	2.5	5.1	25.5	61.2
Number of intersections in 2 centimeters	38	48	54	94

*Stump with water-sprouts.

TABLE 38. RELATION OF SIZE OF VEIN ISLETS TO AGE IN CARYA ALBA KOCH

Diameter of trunk (in centimeters)	22.8	45.6
Number of intersections in 2 centimeters	40	60–62

TABLE 39. RELATION OF SIZE OF VEIN ISLETS TO AGE IN CARYA OVATA KOCH

Diameter of trunk (in centimeters)	2.5	3.8	20.4	45.6
Number of intersections in 2 centimeters	50	56	72	88

TABLE 40. RELATION OF SIZE OF VEIN ISLETS TO AGE IN ACER SACCHARIUM L.

Diameter of trunk (in centimeters)	1.3	2.5	30.6	38
Number of intersections in 2 centimeters	42	52	80	88–94

TABLE 41. RELATION OF SIZE OF VEIN ISLETS TO AGE IN ACER SACCHARUM MARSH

Diameter of trunk (in centimeters)	2.5	45.9	61.2
Number of intersections in 2 centimeters	50	74	90

TABLE 42. RELATION OF SIZE OF VEIN ISLETS TO AGE IN QUERCUS VELUTINA LAM.

Diameter of trunk (in centimeters)	2	3.8	76
Number of intersections in 2 centimeters	50	58	84

TABLE 43. RELATION OF SIZE OF VEIN ISLETS TO AGE IN PLATANUS OCCIDENTALIS L.

Diameter of trunk (in centimeters)	5.1	10.2	20.6	45.6
Number of intersections in 2 centimeters	50	64	68	74

TABLE 44. RELATION OF SIZE OF VEIN ISLETS TO AGE IN FRAXINUS AMERICANA L.

Diameter of trunk (in centimeters)	1.3	30.6
Number of intersections in 2 centimeters	40	80

Size of vein islets in leaves of several varieties of fruits propagated by cuttings

If age affects meristematic tissue in seed-producing plants, the cells of the scions used in propagating certain varieties of fruits must be affected. Unless the process of grafting and growth on seedling stocks restores the youthful condition of the protoplasm of the scion, its leaves should show a size of vein islets typical of the time that has elapsed since the variety originated from seed, not of the time since the graft was made. The application of this venation test in order to determine the physiological condition of present cultivated varieties is most important, but lies beyond the limits of the present paper. However, a few preliminary tests were made of the relative sizes of vein islets in several varieties of cultivated grapes that have been in existence for different lengths of time. Through

the kindness of Dr. U. P. Hedrick, of the New York State Agricultural Experiment Station at Geneva, the pedigreed vines growing there were placed at the writer's disposal, and table 45 is based on them.[3] The vines of Concord, Worden, Catawba, and Diana were of equal size, and all the varieties were growing under apparently identical conditions of environment.

TABLE 45. SIZE OF VEIN ISLETS IN LEAVES OF SIX VARIETIES OF CULTIVATED GRAPES

Variety	Years since origin	Age of individual plant examined	Number of intersecting veinlets in 2 centimeters
Concord	70	14	66
Worden (Concord seedling)	50	14	58
Concord seedling	7	7	35
Catawba	114	14	82
Diana (Catawba seedling)	63	14	74
Diana seedling	5	5	38

The size of the vein islet in these determinations is evidently related to the time that has elapsed since the last seed propagation. Although in the case of four of these varieties many generations of cutting propagation had intervened, in each of which meristematic tissue had been removed from contact with old specialized tissues, nevertheless the decrease with age in size of the vein islets had progressed in much the same way as if contact with the first individual of the variety had been maintained.

Further applications of the venation test to cultivated plants will be discussed subsequently in this paper. (See page 349.)

CONCLUSIONS REGARDING THE SIZE OF VEIN ISLETS AS EVIDENCE OF THE OCCURRENCE OF TRUE SENILITY IN PERENNIAL PLANTS

The results of this study of the leaf venation of the woody perennials mentioned have demonstrated that the size of the vein islets constantly decreases as the plant grows older. The only physical connection between the leaves of this year and those of past years is the meristematic tissue

[3] The writer desires to thank M. J. Dorsey and R. D. Anthony for their assistance in locating cultivated plants used, and for the data regarding the ages of the varieties and individuals.

from which all are developed in their time. If this change in the size of the vein islets is the effect of progressing senility, then the constant changes must be occurring in the meristematic tissue of the plant, and it follows that this tissue must no longer be considered immune from senile degeneration and from death.

There remains to be examined the possibility that the change in size of the vein islets may be due to some cause other than the progressive senile degeneration of the meristematic tissue. The possible causes may be grouped into two divisions: first, changes in the old specialized tissues of perennial plants; second, differences in external conditions resulting from increasing size and subsequent difference in position of leaves.

Is it possible that some progressive change occurring in the early specialized tissues of the root or the stem produces the decrease in size of the vein islets, and therefore no senile degeneration of meristematic tissue need be considered? Any such progressive change either must interfere with the transfer of materials to and from the meristem and the developing leaf, or must act through the production of toxic products that poison the meristem and the leaf.

If the decrease in size of the vein islets is caused by a progressive decrease in the efficiency of the root or the stem as absorbing and conducting organs, then not only the venation, but the size and development of the leaf as well, should be affected. The leaves and the shoots of *Vitis vulpina*, however, show absolutely no signs of impaired vigor of growth. In fact, the leaves and the shoots of very young vines often appear smaller and less luxuriant than those of older vines, due, no doubt, to differences of nutrition received. Furthermore, data given show no relationship between the sizes of the leaves and the sizes of vein islets. The water shoots from the stumps of cut trees and the root shoots of Tecoma, mentioned above, must have had much more than the normal supply of nutritive materials, but this did not markedly change the size of the vein islets. It was found also that leaves borne by cuttings grown under identical conditions showed the same differences in venation as were present on the original vines in their natural habitat.

It should not be overlooked in this connection that the leaves are not the only new structures being constantly produced in perennials. The increase in number of root hairs keeps pace with the number of leaves, and the increasing circumference of the newly formed zones of xylem

and phloëm tends to keep the supply up to the demand. In most perennials conduction occurs largely through tissues that have been specialized but little longer than the leaves. In the plant, as in the animal, the organs present have a capacity above the ordinary requirements of life, and therefore senile degeneration in function can continue for some time before the point is reached at which the efficiency drops below the daily requirement. This interesting point will be considered again under the section dealing with carbohydrate production.

If meristematic tissue does undergo senile deterioriation, then cambium must produce less efficient conducting tissue as time goes on, and ultimately its efficiency will sink to a point at which the leaves will begin to suffer from lack of supplies as well as from their own senile degeneration, and senile death will come apace. In these experiments, however, the older vines, with four exceptions, were in the stage of vigorous maturity and evidently had not reached the stage of inefficient transport. The idea that the differences in size of vein islets is primarily due to difference in efficiency of transport in older parts of the plant must therefore be definitely abandoned.

The possibility of the production of toxic substances by the old parts of the root and the stem, and their being carried up to poison the meristem and the leaf, is a fascinating conception. In the theory of senility which Metchnikoff (1908) has based on the autotoxin conception, the source of the toxin is said to be in man the large intestine and in annual plants the flower; while in order to meet the conditions of the present problem with perennials, the old wood and bark must be considered the guilty organs.

It is possible that autolytic changes occur in the cells of the old specialized tissues of the wood and the bark with the production of various substances. It is possible also that some of these substances may escape from the region of their origin, enter the transpiration stream and be carried to buds and leaves, and accumulate there in sufficient concentration to affect the meristematic tissue. But there is no direct evidence that toxic substances are produced or that such poisoning occurs. On the contrary, the evidence from the studies of venation here described is directly opposed to the theory that the changes in size of the vein islets are due to contact with toxins produced from the old specialized tissues of the plant. In the mature leaves of *Vitis vulpina* growing

under natural conditions, the evident luxuriance of growth and the healthful appearance of the leaves does not suggest the presence of toxins. Any toxin that would act solely on the venation of the leaf could do so only through mechanical obstruction of the vessels. Since any toxins that reach the leaves must be soluble and readily diffusible through protoplasm, such obstructive action is hardly possible.

The fact that the removal of cuttings from contact with the old vine and their subsequent growth on their own newly developed roots did not cause a distinct increase in size of the vein islets in their leaves, is a convincing demonstration of the inadequacy of the toxin theory. If leaves removed from contact with a suspected source of toxins show the same characters as those that remain in contact with it, then the absence of the suspected toxins is established. The possibility that a permanent poisoning may have been produced in the twig before it was removed from the vine as a cutting, is opposed to the universal recuperative power that all life possesses. The growth of cuttings on their own roots or on the roots of seedlings establishes the conditions needed for complete recuperation from the effect of any toxin so feeble as to cause no evident decrease in the vigor of growth, even when contact with continuous contamination is unbroken. The cuttings of large diameter which had several annual rings and had therefore been subjected to any possible toxic action three times as long as had cuttings from the same vine with one ring, produced leaves whose vein islets were of the same size as those in the smaller cuttings.

The idea may be dismissed, therefore, that conduction of toxic products from the stem into the leaves is the primary cause of the decrease in size of vein islets that comes with age. It may be true that there is later some effect of this kind, but it cannot be considered the primary cause. Of course, when the trunk is decaying or is suffering from the attacks of other organisms, the toxins produced are the results of external agencies and the case is one of disease, not senility. Even in such striking cases as those in which great hollows are formed by the decay of the heartwood, the leaves often seem to be suffering no toxic action.

It is possible that one of the accompaniments of senility is an increase of toxic products in the cells. But if such were the case, this accumulation would not be confined to any one class of cells, but would occur in all cells of the senile organism. The cells of the leaf would suffer from their own toxic products as the plant becomes senile, and so would the other

active parts of the plant. The failing activity of each would then hasten the senile degeneration of the others, but would not be the primary cause.

It seems to be true, from the facts brought out in the foregoing discussion, that the change with age in the size of the vein islets in the leaves is not the result of any changes that have occurred in the old specialized tissues of the plant. The evidence demonstrates that neither decrease in the efficiency of excretion nor toxin production in the old specialized cells can account for the change in venation. There remains for investigation the possibility that the changes in size of vein islets may be due to the increasing size of the plant and the consequent change in the position of the leaves.

In the case of the paired vines of *Vitis vulpina*, the external conditions were much the same, and leaves were picked which had been growing under similar conditions of exposure to light. Care was taken also that the leaves selected were growing at the same height above the ground and at approximately equal distances from the bases of the vines. The leaves of the paired vines were therefore growing under much the same external conditions in both the young and the old vines. In spite of this fact they showed the differences in venation that have been tabulated above. Even more striking is the evidence from root shoots and water sprouts of various plants, the leaves of which, although borne close to the ground, possessed vein islets of a size typical of the age of the stump. The sizes of the vein islets in the leaves borne by cuttings raised under identical conditions furnish the final conclusive evidence that differences in external conditions are not the cause of the change of venation with age.

It may be concluded, therefore, that the progressive decrease in size of vein islets which accompanies the increasing age of the perennial plants examined is caused neither by changes in the older parts of the plant nor by the increasing size of the plant. The visible change in venation is therefore the result of a progressive change in the cells of the meristem and of the leaf which is inherent in the nature of their protoplasm. Such inherent progressive change in animal protoplasm is called senility. Animal senility is marked by an initial rapidity and later slowing of its onset, and may be represented by a curve which corresponds to the lower half of a parabola with the equation of the general nature of $(Y-A)^2 = BX$. In such a curve Y represents the condition of function or structure, X represents the age, and A and B are specific constants for the case in question.

By a comparison of the curve of decrease in size of vein islets and that of some recognized senile degeneration in animals, some evidence of the significance of the change in venation may be obtained. In figure 58 two such curves are shown, curve B representing the senile decrease in rapidity of growth of guinea pigs from birth to the age of three months, and curve A representing a decrease in size of vein islets in the leaves of *Vitis vulpina*. Both curves can be expressed by the same equation with different constants, and are essentially of the same type. Similarly, figure 57 (page 315) exhibits the common characters of a senile progressive change in an animal activity and the progressive change in venation in the leaves of cuttings.

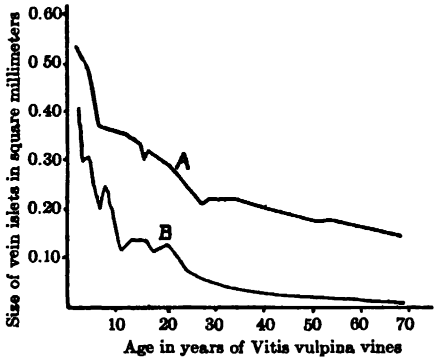

FIG. 58.—*Curves showing* (*A*) *senile decrease in size of vein islets in leaves of Vitis vulpina, and* (*B*) *senile decrease in rate of growth of guinea pigs*

The elimination of other possible causes of the change with age in the size of vein islets, and the marked similarity to typical senility in animals shown by the rate of its progress, is strong evidence that the real cause is senile degeneration of the meristematic tissue and of the cells of the leaf. That the increase with age of vascular tissue in the leaf is a degeneration as regards physiological activity will be made plain.

COMPARISON OF PHOTOSYNTHETIC ACTIVITY IN LEAVES OF YOUNG AND OF OLD PLANTS

It has been shown by Schuster (1908) that the veinlets are of little or no importance in the mechanical support of the leaf. If, therefore, the increase in the proportion of vascular tissue and the consequent decrease in photosynthetic cells result in a decrease of photosynthetic activity, the change in venation with age is a loss without any compensation. Such a loss in photosynthetic activity must obviously accompany the decrease in photosynthetic cells unless the latter improve in efficiency as rapidly as they decrease in amount.

In animals the specialized cells persist for the entire length of life of the organism, and therefore an increase in efficiency of the specialized functions

may occur. There are two principal causes for such an improvement, both resulting from repeated exercising of the special activity involved. The first is the improvement in concerted action between the different specialized tissues involved in even the simplest activity. The second is the increase in size and power of the specialized cells concerned, which not only continues as long as the original impetus of vital activity persists, but is stimulated by the mutual interaction of related tissues. The benefit of practice in athletics, for example, is due to improved coordination in action of muscles, nerves, heart, lungs, and kidneys, as well as to the increased specialized power that exercise stimulates in the cells of the tissues of these organs. In animals, therefore, the increase in efficiency is due to a longer period of interaction and development of specialized tissues.

The specialized tissues in the leaf of the old vine have neither worked longer together, nor had a longer period of development, than the specialized tissues in the leaf of the young vine, and therefore there is no possibility of any such increase in efficiency of any of their tissues as that which may occur in animals. Decrease in assimilating tissue means, therefore, a decrease in the amount of carbohydrate production by the leaf.

In order to get actual figures on this point a number of determinations were made of the increase in weight during daylight by the leaves of old and of young plants. As the leaves of the cuttings were reserved for another purpose, the leaves of the paired vines had to be used. Since in only a relatively few cases a sufficient number of leaves with identical exposure to light could be obtained, the determinations are too few to give more than a general corroboration of the reasoned effect of the change in venation. The impossibility of using gasometric methods on a wide range of wild vines justifies the use of a method that is not strictly accurate, but that is capable of giving at least relative results. The method used was to punch disks, with a Ganong leaf cutter, from both sides, the base, and the apex of each of a number of selected leaves on the paired vines in the morning, and again at night, carefully drying the disks for three days at 80° C., and determining the gain in weight as a percentage of the weight of the morning disks. Only relative results were sought for, and therefore no system for measuring light intensity or recording temperature was used. The disks were killed by steam immediately after

punching, and the various standard precautions were observed in their manipulation. The results with the paired vines are shown in table 46:

TABLE 46. VINES WITH 6 AND 20 RINGS COMPARED AS TO INCREASE IN DRY WEIGHT IN LIGHT

	Number of disks	Morning weight (grams)	Evening weight (grams)	Gain (per cent)
Vines with 6 and 20 rings				
Vine with 6 rings	98	0.2244	0.2530	12.7
Vine with 20 rings	104	0.3099	0.3163	2.1
Vines with 20 and 40 rings				
Vine with 20 rings	95	0.3623	0.3956	9.2
Vine with 40 rings	95	0.2752	0.2996	8.9
Vines with 8 and 25 rings (The day on which this comparison was made was cloudy and dark)				
Vine with 8 rings	52	0.1520	0.1642	8.0
Vine with 25 rings	49	0.1912	0.1900	0.6
Vines with 6 and 20 rings				
Vine with 6 rings	35	0.1761	0.2024	14.9
Vine with 20 rings	35	0.1460	0.1560	6.8
Vines with 5 and 25 rings				
Vine with 5 rings	45	0.1230	0.1336	8.6
Vine with 25 rings	50	0.1394	0.1356	−2.0
Vines with 8 and 24 rings				
Vine with 8 rings	35	0.0832	0.0854	2.6
Vine with 24 rings	69	0.1844	0.1860	0.9

These determinations were made late in August, and are doubtless low in percentage of gain for all the vines as contrasted with carbohydrate formation earlier in the growing season. This does not militate against the results furnishing a fair comparison between the old and the young vines. In fact, it tends to make the test a more delicate one. On very dark days the leaves of the old vines were not able to produce as much carbohydrate as was used, while on the same days the leaves on the young vines adjacent were able to make at least a small gain.

The vines with 20 and 40 rings, used in the second experiment, are not included in the following summary, as both belong to the same class and no results from young vines on the same day were obtained from vines adjacent to them:

Average gain for leaves of vines with from 5 to 8 rings......	9.4 per cent gain in weight
Average gain for leaves of vines with from 20 to 25 rings....	1.4 per cent gain in weight

A comparison between the carbohydrate-producing power of leaves in different stages of development on vines of *Vitis vulpina* gave the following results:

Average gain for leaves from 2.5 centimeters long to mature, 6 rings......	13.3 per cent
Average gain for leaves from 2.5 centimeters long to mature, 15 rings.....	9.2 per cent

A comparison between leaves of *Ampelopsis veitchii* eight years old and nineteen years old, growing on a south wall with as nearly identical light exposure as could be obtained by any means, gave average results as follows:

Average gain for leaves of vine eight years old..........................	15.1 per cent
Average gain for leaves of vine nineteen years old......................	9.7 per cent

CONCLUSIONS REGARDING RELATIVE RATE OF CARBOHYDRATE PRODUCTION IN THE LEAVES OF YOUNG AND OF OLD VINES OF VITIS VULPINA AND AMPELOPSIS VEITCHII

While the difficulty of obtaining leaves with identical light relations on adjacent vines of different ages limited the experiments to but few in number, the unvarying result of the tests is strong evidence in support of the statement made above, that senile deterioration is occurring in the leaves of perennials. It is not probable that translocation is more rapid in the leaves of old plants than in those of young plants. The number of large veins is not increased, and the increase in number of veinlets probably only keeps pace with a decrease in the rate at which materials can diffuse through the cells of the leaf, as will be explained subsequently.

RATE OF ELIMINATION OF CARBON DIOXIDE IN PICKED LEAVES OF VITIS VULPINA OF DIFFERENT AGES

It seemed possible that a comparison of the rate at which carbon dioxide is eliminated from the leaves of old and of young vines would give some

evidence of the relative katabolic activity of the two stages. Since as near the normal respiration as is possible in detached leaves was desired, care was taken not to subject the leaves to other disturbing conditions. The method was as follows: Ten healthy, mature leaves of each vine to be studied were picked and were taken at once to the laboratory. Here they were carefully wiped clean of dust with a soft, dry cloth, the petioles were cut off at the base of the blades, and the blades were weighed. Each set of ten leaves was then placed in an air-tight respiration chamber. The respiration chamber, a 4-liter bottle, was supplied with air which had been drawn in turn through a gas-washing bottle employed as a safety and through a gas-washing bottle filled with a concentrated solution of potassium hydrate. The air leaving the respiration chamber was passed through a calcium-chloride tower for the purpose of removing its water vapor, then through a potash bulb, then through another calcium-chloride tower, and finally through another safety. The air current was provided by means of an aspirator with a regulated outflow.

Eight series of this type were set up side by side in such a way that temperature conditions were the same for all. Tests of old and of young leaves were run simultaneously, and frequent blanks in the different series were employed as checks. The leaves were so arranged in the containers as to prevent their packing together and thus possibly giving rise to such heat production as Molisch (1908) describes. The containers were covered with black paper. The experiments were brought to a close as soon as any indication of injury to the leaves appeared.

In tables 47 to 51 the percentage given in the last column is based on the green weight of the leaf and the weight of the carbon dioxide collected in the potash bulbs and reduced to the average per hour for the entire time of the test. It represents, therefore, the hourly percentage of carbon dioxide eliminated from the green leaves. This rate will be lower than if the dry weight of the leaves could have been used. Since this could not be obtained before the experiment, and the leaves at the end of the test had undergone respiratory losses, the use of the green weight as the basis of calculation was necessary. The leaves from the younger vines contain a greater percentage of water than do those from

the older ones; therefore the use of dry weight as the basis would show a still greater difference in favor of the rapidity of production of carbon dioxide in the younger vines than is evidenced in the following data, in which the green weight is used.

Weighings, and determinations of percentage of carbon dioxide eliminated, were made at the intervals stated in the tables, in which also the total percentage of carbon dioxide eliminated is given. This total percentage is figured as the average rate of elimination per hour for the entire period of the test.

TABLE 47. RATE OF ELIMINATION OF CARBON DIOXIDE FROM PICKED LEAVES OF VITIS VULPINA WITH 20, 6, AND 8 RINGS

Age (years)	Weight of ten leaves (grams)	Weight in grams of carbon dioxide eliminated in successive periods of				Total number of hours	Percentage of carbon dioxide per green weight per hour
		22½ hours	26½ hours	46¾ hours	23½ hours		
20........	26.6	0.2744	0.0534	0.2374	0.0675	119¼	.020
6........	33.3	0.6507	0.0665	0.3478	0.1986	119¼	.032
8........	48.7	0.5662	0.1270	0.3904	0.4060	119¼	.026

TABLE 48. RATE OF ELIMINATION OF CARBON DIOXIDE FROM PICKED LEAVES OF VITIS VULPINA WITH 5, 6, 25, 8, 25, 20, AND 8 RINGS

Age (years)	Weight of ten leaves (grams)	Weight in grams of carbon dioxide eliminated in successive periods of			Total number of hours	Percentage of carbon dioxide per green weight per hour
		20 hours	23 hours	26 hours		
5................	6.5	0.0778	0.0917	0.0678	69	0.052
6................	7.4	0.0211	0.0408	0.1288	69	0.038
25................	14.6	0.0870	0.2115	0.1765	69	0.047
8................	20.0	0.0637	0.2456	0.2504	69	0.041
25................	26.5	0.0076	0.2286	0.4424	69	0.037
20................	12.0	0.0125	0.1819	0.1462	69	0.041
8................	9.8	0.0092	0.2540	0.1262	69	0.057

TABLE 49. RATE OF ELIMINATION OF CARBON DIOXIDE FROM PICKED LEAVES OF VITIS VULPINA WITH 56, 27, 5, 8, AND 7 RINGS

Age (years)	Weight of ten leaves (grams)	Weight in grams of carbon dioxide eliminated in successive periods of			Total number of hours	Percentage of carbon dioxide per green weight per hour
		17½ hours	22 hours	5 hours		
56	8.2	0.0104	0.0584	0.0248	44½	0.026
27	17.0	0.0768	0.0900	0.0448	44½	0.028
5	7.1	0.0492	0.0382	0.0082	44½	0.030
8	18.0	0.0682	0.0584	0.0348	44½	0.020
7	9.3	0.1406	0.0778	0.0300	44½	0.060

TABLE 50. RATE OF ELIMINATION OF CARBON DIOXIDE FROM PICKED LEAVES OF VITIS VULPINA WITH 24, 8, 21, 7, 10, 10, 23, AND 5 RINGS

Age (years)	Weight of ten leaves (grams)	Weight in grams of carbon dioxide eliminated in successive periods of				Total number of hours	Percentage of carbon dioxide per green weight per hour
		19½ hours	24 hours	51 hours	20 hours		
24	22.1	0.0418	0.1334	0.2964	0.0506	114½	0.021
8	10.8	0.0262	0.0814	0.1212	0.0324	114½	0.021
21	30.5	0.0894	0.2812	0.5900	0.1363	114½	0.031
7	27.3	0.0502	0.1350	0.2932	0.0344	114½	0.016
10	15.0	0.0908	0.1548	0.3436	0.0840	114½	0.039
10	25.3	0.0586	0.1398	0.1891	0.0393	114½	0.015
23	14.4	0.0372	0.1009	0.0927	0.0396	114½	0.017
5	7.7	0.0203	0.0692	0.1008	0.0234	114½	0.025

TABLE 51. RATE OF ELIMINATION OF CARBON DIOXIDE FROM PICKED LEAVES OF VITIS VULPINA WITH 6, 9, 18, AND 20 RINGS

Age (years)	Weight of ten leaves (grams)	Weight in grams of carbon dioxide eliminated in successive periods of			Total number of hours	Percentage of carbon dioxide per green weight per hour
		5¼ hours	16¼ hours	32½ hours		
6	9.2	0.0468	0.0632	0.0932	54	0.041
9	15.3	0.0282	0.0606	0.1598	54	0.030
18	16.2	0.0645	0.0407	0.1938	54	0.034
20	11.2	0.0113	0.0354	0.0789	54	0.023

TABLE 52. SUMMARY OF RESULTS ON RATE OF ELIMINATION OF CARBON DIOXIDE FROM PICKED LEAVES OF VITIS VULPINA OF DIFFERENT AGES

Average age of young vines used	7.3 years
Average age of older vines used	25.4 years
Number of determinations made	92
Average length of each determination	23.86 hours
Rate of elimination of carbon dioxide in young vines	.0349 per cent per hour
Rate of elimination of carbon dioxide in older vines	.0297 per cent per hour

The general average for the plants tested indicates that the rate of elimination of carbon dioxide from the picked leaves was about 17 per cent more rapid in the young plants than in the older ones. Any function so complex as respiration is affected by many factors. While conditions were identical in these tests as regards external conditions, and while the results doubtless indicate a true difference in the metabolic power of the respective tissues, nevertheless irregularities are present which point to differences in some factor other than age. The amount of water present is certainly one of these differences.

The respiratory values here shown do not necessarily indicate a slower katabolic activity on the part of each individual cell of the leaf. This may or may not be the case. The total decrease for the leaves of the older plants is doubtless due in part to the lesser total volume of parenchymatous tissue in them as compared with that in the leaves of the younger plants. Whatever the cause of the slower respiration in the older leaves, its presence may indicate that the leaves of the younger vines are more efficient organs.

The evidence presented seems to show that the encroachment with age of vascular tissue on the space occupied by photosynthetic cells in the leaf of a young plant results in decreasing assimilation and respiration. The decrease in size of the vein islets is therefore a real degeneration in the structure of the leaf, just as the invasion of connective tissue into the higher tissues in senile animals is a degeneration. As the replacement of photosynthetic tissue by vascular cells progresses with age, each new crop of leaves will be less efficient in the production of carbohydrates than the preceding crop; and ultimately the plant will begin to suffer from lack of food, and if no other cause of death intervenes it will in time starve to death. The rapidity of the progress of senile degeneration in plants varies with the species, as it does in animals, but ultimately senile death will occur.

It is not possible at present to state the precise nature of the change in meristematic cells which forces the production of more vascular tissue at the expense of parenchymatous tissue. Later in this paper an attempt at an explanation will be made.

IMBIBITION OF WATER BY POWDERED LEAVES OF YOUNG AND OF OLD VINES

The amount of water imbibed by the powdered tissues of leaves gives an indication only of the relative water-holding capacity of the living leaves. Is there any difference in the behavior of leaves from young and from old vines toward water of imbibition?

A large number of leaves were collected from various vines of *Vitis vulpina* with from six to eight rings and from twenty to twenty-five rings. These leaves were ground fine in a meat grinder. Each ground mass was immersed in acetone for ten minutes, filtered under suction, and dried in a crucible for three days at a temperature of 90° C. The dried masses were then thoroughly pulverized in a mortar to the same degree of fineness, the heavier veins and the more numerous veinlets of the older material requiring more grinding than the younger. There were thus obtained about 100 grams of leaf powder from the younger vines and the same quantity from the older ones. The individual vines were not kept separate but all those of similar age were mixed together.

DEGREE OF IMBIBITION WITH DISTILLED WATER

In order to determine the degree of imbibition of water by powdered leaves from young and from old vines the procedure adopted was as follows: In three graduated glass tubes was placed 0.5 gram of the powder from leaves of young vines, and into three other tubes the same quantity of powder from leaves of old vines. Distilled water was added to each. The material from young vines increased in bulk from a height of 30 millimeters to one of 50 millimeters, while that from old vines increased only from 25 to 38 millimeters; the percentage increase of the leaves from the young vines being 66, and that of the leaves from the old vines being only 52.

This result proved to be a constant one, there being minor variations in the percentages, but the powder from the young leaves always averaging about 14 per cent greater absorption. This difference might be due to a

greater power of imbibition in the cellulose and protoplasm of the young tissues, or, as Fischer (1910) has shown, to a greater degree of acidity in the younger cells. That Fischer's results for animal colloids hold, to some degree at least, for plant colloids, is indicated by the following test: In the bottom of each of six graduated glass tubes was placed 0.2 cubic centimeter of leaf powder from the old leaves, and into each tube was poured 2 cubic centimeters of distilled water or of the concentrations of oxalic acid indicated below. The concentration of oxalic acid is expressed in terms of gram-molecular solution. The results are shown in table 53:

TABLE 53. EFFECT OF DIFFERENT CONCENTRATIONS OF OXALIC ACID ON ABSORPTION OF WATER BY POWDERED LEAVES

Test tube	Added 2 cubic centimeters of	Time (hours)	Height of column of swollen powder (centimeters)
A	Distilled water	24	2.8
B	0.005 oxalic acid	24	3.8
C	0.02 oxalic acid	24	4.5
D	0.1 oxalic acid	24	3.8
E	0.5 oxalic acid	24	3.3
F	Distilled water	24	2.7

The swelling was greater in the weak acids than with distilled water, and reached a maximum at 0.02 molecular solution of oxalic acid.

The fact that the powder from the young leaves swells more than that from the old leaves may therefore be due to the fact that the leaves of the young vines are richer in some organic acid than are those of the old vines.

RELATIVE ACIDITY OF THE YOUNG AND THE OLD POWDERED LEAVES

In each test tube 0.2 gram of powder was placed, 2 cubic centimeters of distilled water was added, and the test tube was shaken. The acidity of the water was then neutralized by titrating with 0.1 normal KOH,

phenolphthalein being used as an indicator. The powder does not in any way interfere with the use of this indicator.

TABLE 54. RELATIVE ACIDITY OF LEAF POWDER FROM YOUNG AND FROM OLD VINES

Amount (in cubic centimeters) of 0.1 normal KOH solution required to neutralize 0.2 gram of

Powder of young leaves	Powder of old leaves
2.8	1.4
2.8	1.6
2.5	1.6
2.0	1.6
2.0	1.6
2.0	1.6
2.0	1.3
1.9	1.3
Average.......... 2.2	Average....... 1.5

The powder from the leaves of the young vines, therefore, has a greater degree of acidity than that from the leaves of the old plants. This is a distinct difference between the leaves of plants of different ages. The significance of this difference as regards physiological activity cannot be certainly indicated. It may affect the degree of turgidity and the permeability of the cells of the leaves.

IMBIBITION AFTER NEUTRALIZATION

In order to see whether the greater acidity was the sole cause of the greater swelling, experiments were made in first neutralizing the solution, then washing it, and then adding 0.02 molecular solution of oxalic acid and noting whether differences in swelling still appeared. In these experiments 0.2 gram of leaf powder was placed in each test tube and 2 cubic centimeters of distilled water was added. Each solution was then neutralized with 0.1 normal KOH and washed. Two cubic centimeters of 0.02 molecular solution of oxalic acid was then added, with a trace of thymol, and the tubes were left for twenty-four hours. The wet powder, after being gravity-drained for five minutes in the inverted test tube, was weighed and the percentage of imbibed water was calculated as a percentage of the weight of the dry powder. The results are shown in table 55:

TABLE 55. AMOUNT OF WATER IMBIBED BY LEAF POWDER FROM VINES WITH FROM 6 TO 8 AND FROM 20 TO 25 RINGS

	KOH (cubic centimeters)	Oxalic acid (2 grams of)	Height of column (millimeters)	Weight of imbibed water (grams)	Percentage of imbibed water
Young leaves					
1	2.00	.02 mol. sol.	53	0.9968	498.4
2	2.00	.02 mol. sol.	53	0.9298	464.9
3	1.95	.02 mol. sol.	54	1.0018	535.9
Old leaves					
1	1.40	.02 mol. sol.	48	0.9458	472.9
2	1.35	.02 mol. sol.	46	0.7948	397.4
3	1.30	.02 mol. sol.	42	0.8168	408.4
Young leaves					
1	2.80	.02 mol. sol.	....	0.9588	474.4
2	2.80	.02 mol. sol.	....	0.9852	479.1
3	2.50	.02 mol. sol.	....	0.9847	492.4
4	2.00	.02 mol. sol	....	1.0194	509.7
5	2.00	.02 mol. sol.	....	0.9141	457.1
Old leaves					
1	1.60	.02 mol. sol.	....	0.6076	303.8
2	1.60	.02 mol. sol.	....	0.6692	339.6
3	1.60	.02 mol. sol.	....	0.7512	375.6
4	1.60	.02 mol. sol.	....	0.5875	293.8
5	1.60	.02 mol. sol.	....	0.8054	402.7
6	1.60	.02 mol. sol.	....	0.9938	496.9

General average of percentage of imbibed water for young leaves......... 489.0 per cent
General average of percentage of imbibed water for old leaves............ 387.9 per cent

The substance of the younger leaves has a greater inherent property of imbibing water than that of the older leaves. Some of this difference, no doubt, is due to the greater proportion of vascular tissue present in the older leaves, but the difference in percentage of imbibition seems to be greater than would be caused by the difference of vascular tissue. This greater capacity of imbibing water, if present in living leaves, must play a part in the distribution of substances among the cells, as well as directly affect other activities of the protoplasm.

OTHER EVIDENCES OF SENILITY

The investigations on veinage, photosynthetic activity, respiration, and imbibition point to the conclusion that leaves of old vines have suffered senile degeneration and that they are less efficient organs than leaves of young plants. Since such a very marked character as veinage is altered by age, it is probable that other differences exist between leaves of

young and of old vines. A certain number of observations made indicate that there are other structural and cell differences, and, while the evidence is not fully conclusive, it is at least suggestive and tends to further support the idea that senile changes occur in the leaves of Vitis. The observations are herewith recorded.

COMPARISON OF NUMBERS OF STOMATA IN LEAVES OF YOUNG AND OF OLD VINES OF VITIS VULPINA

Comparisons of numbers of stomata per square millimeter were made with leaves borne by cuttings grown in distilled water under identical greenhouse conditions. Thin flakes of epidermis were removed with a very sharp razor from different leaves of different cuttings, were mounted in water, and were measured as to the number of stomata. From each flake a vein islet of rectangular form was selected, its area measured, the number of stomata counted, and the number to the square millimeter calculated. The results are shown in table 56:

TABLE 56. COMPARISON OF NUMBER OF STOMATA IN LEAVES OF VITIS VULPINA

	Number of stomata to 1 square millimeter in		
	6 vines with from 5 to 7 rings	4 vines with from 8 to 10 rings	6 vines with from 20 to 30 rings
	82	105	247
	100	128	314
	133	138	288
	115	112	266
	115	125	266
	112	120	246
	165	150	266
	96	125	292
	119	155	300
	107	....	290
	112	....	330
	157	....	256
	115	....	314
	124	....	314
	144	....	247
	86	....	....
	105	....	....
Average..........	117	129	282

It has been shown by Mer (1886), by Dufour (1886), and by Schuster (1908) that the same species of leaf possesses more stomata to a unit of

surface when growing in strong light than when growing in the shade, and Brenner (1902) has stated that at first, when leaves are moved into the shade, the increase in their size due to greater humidity causes the stomata to become farther apart, but that later new *Anlagen* are formed and the number is brought back almost to that found in sun-lit leaves. The differences in number of stomata per square millimeter on the leaves of *Vitis vulpina* given above, however, cannot be due to any difference in light exposure or humidity or available water, since the leaves used were borne on cuttings grown under identical conditions. It was noted also that the average size of the apertures of the stomata decreases with age, as does also the size of the guard cells. The figures given in table 57 were obtained from accurate measurements made on the same material as was used for counting stomata. Since the width of the apertures varies directly with the degree to which the stomata are open, while the length of the apertures is approximately the same at all times, the measurement selected as best representing the size of the stomata was the long diameter of the stomatal opening between the guard cells. Measurements of the width of the apertures of stomata when fully extended indicated that the relation of the long to the short diameter was much the same in both young and old vines. The long diameters of the stomata can therefore be used as a measure of the size of the apertures.

TABLE 57. SIZE OF STOMATA IN VITIS VULPINA OF DIFFERENT AGES

	Long diameter of aperture in 6 vines with from 5 to 7 rings (microns)		Long diameter of aperture in 6 vines with from 20 to 30 rings (microns)
	18.3		9.2
	14.6		9.2
	14.6		11.0
	18.3		12.8
	18.3		9.2
	14.6		9.2
	18.3		11.0
	14.6		12.8
	22.0		9.2
	18.3		11.0
	14.6		12.8
	14.6		9.2
	18.3		9.2
	14.6		11.0
	14.6		14.6
Average.........	16.6	Average........	10.8

COMPARISON OF SIZES OF PALISADE CELLS IN LEAVES OF YOUNG AND OF OLD VINES OF VITIS VULPINA

The cells of the palisade layer are much more regular in size and form than any others in the leaf, and therefore best adapted for the determination of the effect of increasing age on the size of the cells of the leaf. In table 58 the measurement given is the length of the cell measured perpendicularly to the surface of the leaf, as seen in cross section.

TABLE 58. SIZE OF CELLS OF THE PALISADE LAYER OF LEAVES OF YOUNG AND OF OLD CUTTINGS OF VITIS VULPINA

	For 3 vines with 5 rings (microns)		For 3 vines with 20 rings (microns)
	14.6		11.0
	11.9		11.0
	11.9		11.0
	11.9		9.0
	12.8		11.0
	11.9		14.6
	12.1		10.0
	11.9		11.0
	11.0		9.0
	12.0		9.0
	11.0		9.0
	14.6		9.0
	11.0		9.0
Average.........	12.2	Average.........	10.3

The cells of the palisade layer thus show a distinct decrease in size even in the leaves of the plants twenty years old, which are in their vigorous maturity. The guard cells of the stomata, in the cases observed, also show the same change in size with age. This change in size shown by the two most regular cells of the leaf is seemingly apparent in all the photosynthetic cells as well. As regards the cells of the veinlets, this decrease in size with age is doubtful and will require more study. It is possible that the physiological stimulus which calls forth an increasing development of vascular tissue in the older plants may likewise so stimulate the development of the vascular cells as to neutralize, for a time, the tendency toward a reduced size. Some evidence to this effect has been observed.

These few observations indicate that possibly there is a difference in number of stomata in the leaves of young and of old vines, together

with changes in guard cells and palisade cells. The results are not conclusive enough to permit of definite conclusions, and the inadequacy of the evidence does not warrant any explanation of its significance. Suffice it to say that an increased number of stomata with smaller apertures, while not permitting greater diffusion of carbon dioxide or oxygen than the stomata of young leaves, would be a benefit to the plant in bringing a larger area of palisade cells in closer proximity with air chambers. If the permeability is decreased in the cells of leaves of old vines, then a larger number of stomata per unit area would tend to counterbalance the defect of decreased permeability. The stimulus to the production of an increased number of stomata cannot be otherwise explained at the present time.

RELATIVE MASS OF NUCLEUS AND CYTOPLASM IN CELLS OF THE LEAF IN YOUNG AND IN OLD VINES OF VITIS VULPINA

It will be remembered that the advance of senility in animal cells is marked by a decrease in the relative amount of nuclear material as compared with the amount of cytoplasm. Difficulty was experienced in making such a comparison in the cells of the leaf, because of individual differences in the sizes of the nuclei of adjacent cells. The rapidity with which a cell is working is indicated usually by temporary changes in the size of its nucleus. The cells in the assimilating tissues of the leaf seemed to be in different stages in each preparation, and the differences were great enough to render doubtful the value of averages. The cells that did show some uniformity in this respect were the border parenchyma cells of the veinlets, and a series of measurements was made of these with the following results:

Proportion of cytoplasm to nucleus in vine with from 5 to 7 rings, 388 to 1
Proportion of cytoplasm to nucleus in vine with from 20 to 30 rings, 478 to 1

The great difference in the lengths of these cells makes the calculations, even in the border parenchyma cells, unsatisfactory. This comparison between nuclear and cytoplasmic material can probably be carried out with greater accuracy on the meristematic tissue in the stem. In the investigation of the effect of age on the tissues of the stem, which will be the next phase of the problem attacked, a careful study of the proportion of cytoplasm to nucleus will be made.

SUMMARY

1. The size of vein islets in the leaves of *Vitis vulpina* is independent of the area and thickness of the leaves, and is influenced only slightly by differences of exposure to light.

2. The vein islets in the leaves of *Vitis vulpina* become smaller as the vine becomes older. This decrease in size of vein islets is due to encroachment of vascular tissue.

3. Leaves borne on plants vegetatively reproduced show vein islets similar to the plant from which the original cuttings were secured. Only plants reproduced sexually show vein islets larger than those of the parents.

4. The same difference with age in the size of vein islets occurs in *Vitis bicolor*, and apparently in a considerable number of other woody perennials.

5. The decrease in size of vein islets means reduction in number of photosynthesizing cells, and the evidence shows that for leaves of old vines there is a decrease in the rate of photosynthesis.

6. There is also a decrease in the rate of respiration (evolution of carbon dioxide) in picked leaves.

7. Leaves of young vines have a greater capacity for imbibing water than have leaves of old vines, which may be the result of less vascular tissue in the former.

8. There is probably an increase with age in the number of stomata per square millimeter.

9. There is probably a decrease with age in size of stomatal aperture and of guard cells.

10. There is probably a decrease with age in size of palisade cells.

11. There is probably a decrease with age in the mass of nuclei of border parenchyma cells.

DISCUSSION

It is believed that the evidence presented is fairly conclusive that the changes discussed are due neither to external factors nor to internal factors other than those produced in the meristematic tissues by age, and that they must therefore be ascribed to the action of true senile degeneration of the type found in animals. The positive evidence that these changes are senile ones rests on three fundamental similarities which they show to senile degenerations occurring in animals: the first marked similarity is that the rate of change, as shown by tables and curves, is strikingly

similar; the second is the fact that such physiological activities as are common to both plants and animals—respiration, for example—show the same changes with age; the third is the nature of the morphological changes. Although the structure of these plants is so different from that of animals that detailed comparisons in but few specific organs can be made, nevertheless the recognized theories of the causes of the senile changes in animal structure, if applied to plant organs, would call for such morphological degenerations as have been shown in this paper to exist in the leaves. Since these theories are given later, their application to this point will not be repeated here. In the case of senile changes in cells, while the proportion between the mass of nucleus and that of cytoplasm in young and in old leaf cells of *Vitis vulpina* was not determined without possible error, the considerable change in the proportion found with age seems too great to be ignored. The nature of the change in nuclear mass in these leaf cells is the same as that found in animal cells.

When considered in its entirety, the evidence that these changes are visible expressions of senile degeneration in the meristematic protoplasm seems to be reasonably substantial. At any rate, any other explanation of these changes in the leaf would be much more difficult to maintain.

If this be granted, it will be interesting to apply these tests of age to the long-disputed problem of the effect of continued vegetative propagation as compared with that of seed propagation. Heretofore no evidence of senility could be used that was not open to the objection that it might be merely the effect of some external agency.

SIGNIFICANCE OF SENILE CHANGES TO THE PROBLEM OF THE RUNNING-OUT OF VEGETATIVELY PROPAGATED FRUITS

The first publication of importance regarding the possibility of senile deterioration was that by Thomas Andrew Knight (1795), who attributed to this cause the gradual failure of different varieties of apples and pears. Having tried experiments in grafting scions from young and from old seed-grown trees of different ages, Knight decided that the cuttings were directly influenced by the age of the plant from which they were taken. He concluded that a variety propagated by cuttings would not be vigorous much beyond the age of the parent tree. He turns to nature for a most interesting support of his theory regarding the inherent defect of vegetative reproduction. Certain trees, he says, such as the aspen and some

others, send up a multitude of shoots from the roots, while most of the wild trees are limited to seed propagation; and he adds, "Were a tree capable of affording an eternal succession of healthy plants from its roots, I think our woods must have been wholly over-run with those species of trees which propagate in this manner, as those scions from the roots always grow in the first three or four years with much greater rapidity than seedling plants."

In 1810 Knight published a paper entitled *On the Parts of Trees Primarily Impaired by Age*, in which he makes the following statement: "I am, therefore, much disposed to attribute the diseases and debility of old age in trees, to an inability to produce leaves, which can efficiently execute their natural office . . . . It is true that the leaves are annually reproduced, and therefore annually new; but there is, I conceive, a very essential difference between the new leaves of an old, and of a young variety."

Following Knight's first paper (1795) many observations which agreed or disagreed with his results were reported in English and Continental horticultural and gardening publications. None of these reports were more than casual notes.

The first paper of interest after Knight's was that by Jessen (1855), who strongly supported Knight's theory and introduced the term *sorte* to include all the plants grown from the cuttings of a parent plant. He believed that all the members of a *sorte* would grow old together.

In some degree the results of Bouche and Bolle (1875) supported Knight in the case of the cultivated olive tree.

The first paper to make a serious attack on the theory was that published by Sorauer in 1877. Sorauer maintained that cuttings showed the same type of differences among themselves that seedlings did, and might serve the same purpose without producing serious degeneration.

In 1882 Hildebrand published a long discussion on the duration of life in plants and the effect of various external factors in increasing or decreasing to some degree the constitutional duration. While this paper is full of interesting facts regarding this point, it nowhere touches the problem of senility as affecting constitutional duration, and therefore Hildebrand's results do not directly concern the present study.

Burgerstein (1895) made some observations on the relation of vegetative propagation to degeneration, arguing against its possibility.

The best review of the whole question is by Möbius (1897), who cites at considerable length the various observations on the conditions of those cultivated plants of to-day which have long been vegetatively propagated. His conclusion is that no senile deterioration in such plants has been proved to exist. He maintains that meristematic tissue is true embryonic tissue in the same sense as is the tissue in the embryo sac, and that there is no theoretical reason why propagation by cuttings should be different in its results from that by seeds. He believes that it has been shown by various published accounts that the banana, the grape, the date palm, the fig, and the Chinese yam (*Dioscorea batatas*), have been propagated for from two thousand to four thousand years by means of vegetative methods without degeneration. The number of writers which he cites is very large and could be greatly increased, but practically none of these reports can be considered as offering evidence of value.

It is evident, therefore, that the problem is still unsolved. It must be remembered that the lowest plants known to-day are apparently sexless, and capable of vegetative reproduction only. There can be little doubt of their ability to propagate their kind continuously over long periods of time. Only in those plants and animals which have developed sexuality and sexual reproduction, can the question of possible degeneration through long-continued vegetative propagation be seriously raised. Undoubtedly sexual reproduction efficiently rejuvenates protoplasm. Apparently it is also true that rejuvenescence is accomplished in the primitive sexless plants by an equally efficient method. In those higher plants that have lost their sexuality, it is possible that the loss of sexuality has been accompanied by the regaining of a more primitive method of rejuvenescence. It is in the seed-producing cultivated plants, the varieties of which are vegetatively propagated, that the problem of the relative efficiency of the two methods in rejuvenating protoplasm is presented with the least degree of complication.

First, therefore, such cultivated plants as the grape and the date should be dealt with, and later the more complicated cases, such as the Dioscorea. The records of the cultivation of the seed-producing fruits are not sufficiently complete to assure beyond question that the varieties which have been so long cultivated have not been replaced at intervals by seedlings. To-day, for example, countless seedlings of Concord grapes are being grown. Some of these develop into plants almost identical in vine and fruit with

the original Concord. It is not beyond the bounds of possibility that some grape grower might confuse such a seed-produced vine with a true Concord graft. The younger vine might be utilized as a source for cuttings, and these in time might displace the older stock without any one's being the wiser. The possiblity of such propagation was greater in the past than it is to-day, and holds for every seed-producing cultivated plant. It is possible, therefore, that some of the seed-producing plants which are cited as conclusive evidence of the harmlessness of long-continued vegetative propagation have been sexually propagated at intervals.

The recognition of degeneration in cultivated varieties is rendered difficult by the very long life attained by woody perennials as compared with the life of man. Many trees have a natural life spanning several generations of men. Such plants would show little change in a single generation. The possibility of using the data gathered by the preceding generation as a test of deterioration of fruits to be utilized by following generations has been practically impossible in the past. The only criteria of degeneration known in the past have been such characters as yield of fruit and resistance to disease—in other words, characters that are profoundly affected by external conditions as well as by internal ones. It is evident that such characters cannot enable the growers of one generation to accurately compare the past and the present conditions of any varieties. Since investigators of to-day cannot make a mathematical summation of the combined effects of all the external factors that are operating throughout a season on a given plant, the inherent weakness of past comparisons needs no further comment. And yet all the arguments concerning the problem of the effect of vegetative propagation have been based on such comparisons and on theoretical considerations.

The chief theoretical assumption opposing the idea of degeneration through long-continued vegetative propagation in cultivated fruits has been that of the immunity of meristematic tissue to senile changes. The results of the present study of the senile changes in the leaves of *Vitis vulpina* argue against the truth of this assumption. What is of greater importance, in its practical application, is the discovery of specific morphological changes in the leaves as the plant grows old, which appear to be independent of external conditions and therefore available for use as tests of the physiological condition of the plant. It is hoped that the change in venation will prove in practice to be applicable to a wide range

of cultivated plants as a practical and convenient method for the determination of the degree to which senile degeneration is present in any specific plant or variety of fruit. Whether it is also applicable as a test for the effect of apogamy has not been investigated.

While the purposes of this paper do not include the application of its findings to vegetatively propagated cultivated fruits, a few examinations of the venation of the leaves of certain varieties were made as preliminary tests and the results are given in table 59. The results obtained in the case of six varieties of grapes have already been stated, but for convenience will be repeated in the table. All plants examined were pedigreed plants growing in the orchards of the New York State Experiment Station at Geneva, New York, to which the writer had access through the kindness of Dr. Hedrick and his assistants.

TABLE 59. SIZE OF VEIN ISLETS IN SEVERAL VARIETIES OF FRUITS PROPAGATED BY CUTTINGS

Variety	Number of years since origin	Age of plant examined (years)	Number of intersecting veinlets in 2 centimeters
Concord grape	70	14	66
Worden (Concord seedling)	50	14	58
Concord seedling	7	7	35
Catawba grape	114	14	82
Diana (Catawba seedling)	63	14	74
Diana seedling	5	5	38
Lady apple	300	18	49+
Baldwin apple	92	18	41
Hubbardston apple	82	18	45
Hubbardston seedling	15	15	30
Seckel pear	100	20	54+
Seckel seedling	7	7	38
St. Catherine plum	215	10	52
Italian Prune plum	100	10	48
Green Gage plum seedling	15	15	33
Jefferson plum seedling	2	2	16
Red Cheek (Red Cheek Melocoton) peach	100	8	85+
Late Crawford peach	50	8	53
Elberta peach	25	8	41

In the cases of the Seckel pear and the Red Cheek peach the veinlets were too intricately branched to be accurately counted.

The leaves used for these data were picked at approximately the same height from the ground and care was taken that all had the same light exposure; so that conditions in each were as nearly alike as possible. The soil and the cultivation were apparently the same for each. Ten leaves were picked from each tree and the venation count given in the table is the average of the ten. At the time the venation count was made the writer did not know the respective ages of the varieties. An arrangement of the varieties in the order of their venation count proved an accurate forecast of the respective varietal ages as subsequently learned.

In so far as this preliminary test goes, therefore, it supports the view that propagation by cuttings does not prevent the progress of senile degeneration in the tissue of the cuttings. A number of interesting points suggest themselves on examination of table 59. In the case of the peach, probably the shortest-lived fruit represented in the table, it seems significant that the rate of decrease in size of vein islets is more rapid than in any of the others. Some species seem to have an original size of vein islets greater than closely related varieties. It is possible that such an initial large size of islet is a mark of physiological vigor, and indicates greater constitutional strength and a longer productive life than is the case with those plants with smaller islets. This point might well be considered by plant breeders in selecting breeding strains. On the other hand, some varieties—the grape, for example—seem to show a marked slowing of the rate of decrease in size of islets after maturity, and thus attain a considerable age in spite of the rather small initial size of the islets.

The possibility of determining the age of a plant by the size of the vein islets in the leaves opens the way to a comprehensive determination of the present physiological condition of the different varieties of fruits. The results obtained from the study of *Vitis vulpina* and the preliminary tests of cultivated fruits seem to indicate that all varieties of fruits now vegetatively propagated must in time run out. A wise provision for the future of the fruit industry must therefore include an investigation into the physiological condition, as regards senile degeneration, of each variety. Such a study may show some varieties to be capable of some degree of rejuvenescence through processes similar to those found in sexless plants, or it may show that all are doomed to extinction. Certainly, the determination of the fact is important. If certain varieties must shortly show deterioration, plant breeders must pay particular attention to developing

seedlings capable of replacing them. Such seedlings having been developed, their propagation by cuttings may then be continued until physiological deterioration again appears and recourse to a new seedling variety is necessary. It may thus be possible to so classify and control cultivated fruits that all loss from degeneration may be accurately foreseen and prevented.

Before leaving the subject of the effect of vegetative propagation on different varieties, it may be well to point out that in those cases in which senile degeneration has progressed so far that the conduction of nutritive materials to the leaves is markedly interfered with, the removal of a scion and its insertion into a seedling stock should result in an improvement in its nutritive supply. This may produce a certain increase in activity, but not rejuvenescence since the cells of the scion are not changed.

The effect of vegetative propagation on plants other than fruits, potatoes, hops, and the like, is also of great importance. The general opinion among growers seems to be that those varieties which have been long propagated in this way are showing decrease in yield and in resistance to disease. No preliminary applications of the venation method have been made in the case of these plants. Where such evident adaptations for vegetative propagation as tubers, bulbils, and the like are present in plants, the possibility of the presence of other than sexual methods of rejuvenescence seems greater than in plants without such special equipment. An examination of the leaves borne by trees and root shoots of Lombardy poplar (*Populus nigra italica* Du Roi) — which has lost its power to produce seeds but sends up multitudes of root shoots, and which has been propagated artificially by cuttings for about seven hundred years — showed the vein islets to be so divided by minute veinlets of procambial tissue as to make measurement very difficult. The application of the venation test to other cultivated plants vegetatively propagated should give interesting results and will be undertaken.

BEARING OF THESE FACTS ON THEORIES OF SENILITY

The steady encroachment with age of the vascular tissue of the leaf on the space originally occupied by the photosynthetic cells, and the accompanying decrease in the photosynthetic power of the leaf, must be forced by some physical or chemical change occurring in the cells.

In other words, it must be a visible effect of a progressive senile change occurring in the meristematic cells which produce the leaf.

An examination of the vein islets under the microscope shows that a majority of the photosynthetic cells are not in direct contact with the veinlets. Such cells must get their water and inorganic nutrients by osmosis and diffusion through the cells which separate them from the veinlets, and all outgoing materials must also pass through the enclosing cells. The larger the vein islet, therefore, the greater will be the average distance through which materials must be conducted before they reach the veinlets or the cells. It is obvious that the maintenance of efficient ingress and egress is vital to the life of the cells and the life of the plant. Since most of the cells are dependent on the ability of surrounding cells to conduct materials, the process of diffusion through photosynthetic cells is of vital importance to the whole plant.

The results of Askenasy (1870), Volkens (1884), Massart (1902), and Schuster (1908) indicate that if the cells of the leaves are suffering for water additional veinlets are produced. In other words, the development of veinlets is in part controlled by the condition of the cells supplied by them. If the photosynthetic cells are suffering from the lack of something which the veinlets can supply, the effect is to stimulate the development of additional veinlets. An interesting theory of the origin of the small blood vessels in the developing animal embryo, advanced by Mühlmann (1900), is based essentially on the same idea. As each aggregate of cells in a developing embryo increases in size, its central cells will be pushed farther away from the blood vessels at its margin. Finally this distance becomes so great that osmosis and diffusion through the intervening cells cannot efficiently provide for the needs of the central cells. This lack of efficient nutrition and excretion causes certain modifications in the cellular activities. These specific modifications stimulate the formation of branches from the original blood vessels, which penetrate the cell aggregate. The entrance of the blood vessel is physiologically the equivalent of a reduction in the size of the aggregate.

In the leaf of the young plant, the vein islets are as large as will permit efficient conduction to and from the central cells. There is no further increase in size. But if the protoplasm of the cells of the aggregates changes with age in such a way that osmosis and diffusion through them are being rendered increasingly difficult, the physiological effect will be

equivalent to an increase in the distance from the veinlets. If one effect of age on the plant protoplasm is to decrease its permeability to any or all of the substances that pass in and out of the cell, the effect on the central cells of the vein islets will be essentially the same as removing them further from the veinlets.

On the assumption that such a decrease in permeability is one of the marks of senile degeneration occurring in plant cells, the differences between the sizes of vein islets, the number of stomata, the size of the cells, and the physiological activities, found between the leaves of young and of old plants, can be rather plausibly explained. The smaller size of the cells with age causes an additional interference with the freedom of osmosis; but this, it is believed, is secondary to the change in permeability, and probably is a result of it. The evidence given here of a possible decrease in permeability as a senile change in protoplasm, suggests its application to the theories of senility.

THEORIES OF SENILITY

The theories of senility may be grouped in two general classes: (1) those considering the cause to be failure of some specific organ in the body, and (2) those considering the cause to be specialization of the cells or change in the physiological activities of the cells. The theories in the first class cannot be considered as fundamental.

Localization of senile changes

Demange (1886) and Osler (1892) considered arterial sclerosis as the cause of senility, while Lorand (1912) ascribed senility to a degeneration of the thyroid and other ductless glands. Metchnikoff (1903 and 1908) explained senile degeneration in man as due to the action of intestinal bacterial toxins, and in plants to the formation of poison in the flowering shoot.

Metchnikoff's theory of the poisoning of the body by toxins produced in one part of it represents merely a different phase of the " guilty-organ " class of theories. He thinks that it is the large intestine in man, and the flowering shoots in the higher plants, that serve as centers of poison production which ultimately poisons the whole organism. In animals he considers the poison to be produced by bacteria in the intestine. The toxins thus formed are carried to all parts of the body by the blood; and

attack various tissues with different degrees of success. Those cells that cannot successfully withstand the effects of the poison are weakened and destroyed by the independent predatory cells of the body — the phagocytes. Those plants that die soon after producing their seeds, Metchnikoff believes to have been poisoned by poisons formed in the flowers during seed production, which spread from the flowers to all parts of the plant and kill it.

Here again the theory is based on the conception that but one part is the cause of senility — that in spite of the fact that all the cells have a common origin in the development of the animal or the plant, only those of one organ are the producers of senility. As regards both plants and animals, Metchnikoff's theory is obviously of very limited application, being inapplicable to animals without the large intestine and to flowerless plants. As regards flowering plants, moreover, the enormous span of life attained by those that produce annually myriads of flowers and seeds is sufficient to eliminate further consideration of the poisoning theory as of primary value.

As regards animals, furthermore, Metchnikoff's theory is not so much a theory of senility as a denial of senility. In so far as he considers the cause of natural death to result from toxins produced by bacteria, he is denying the existence of natural death. In all bacterial diseases their toxins are the most important factors in the production of harm, whether they are localized in the intestine or in the tissues, and when death results from bacterial toxins it is due to disease, not to senility.

Disease is an interference with the vital activities, produced by unfavorable conditions — such as attacks of microscopic organisms inherited or acquired, structural defects in one or another organ, or the like. Senility, on the other hand, produces an inevitable death in spite of the most favorable external conditions and when all organs are sound. It has been shown that in senile degeneration all tissues have undergone a structural and physiological deterioration, and therefore all organs are involved.

Attempts to single out one particular organ as the sole agency of senility are therefore not supported by evidence and are based on a superficial conception of the process.

Cell specialization

As the seed or the egg develops into the mature organism, the embryonic cells gradually develop the typical cytoplasmic characteristics that mark

the adult tissues. The cytoplasm not only increases in amount relative to the nucleus, but becomes structurally differentiated as well, both changes being of such a nature as to fit the cell for the efficient performance of the special work that it is to perform for the whole organism.

Minot, in 1891, was the first to advance the theory that this specialization of the cell was the cause of senility. He maintained at that time and later (1908) that the advance in efficiency in the function utilized by the organism was at the expense of the functions necessary to the continuous vigor of the cell. According to his view, therefore, each advance in efficiency of a special function was at the cost of deterioration in the self-sustaining power of the cell, and this deterioration he considered to be the true senile degeneration, which progressed to a final natural death.

Hertwig (1906) agrees with Minot's theory to this extent, expressing his idea in his own terms. He says that a free cell is completely free to carry on the activities required in order to maintain the vigor of the cell, and these activities he includes in the term *cytotypical*. The cells of the embryo, while largely under the cytotypical laws, are to some extent modified in their actions by the *organotypical* laws, which govern the interactions of the cells in each many-celled organism. As development proceeds, the cytotypical laws are gradually dethroned by the organotypical, with the same result as that postulated by Minot.

In another respect, however, Hertwig differs from Minot. Minot maintains that cytoplasmic differentiation is irreversible, that having once started it must continue to senility and death. Hertwig, on the other hand, believes that under certain conditions the specialized cells can throw off the organotypical yoke and become again cytotypically active. His theory of cancer, for example, is that its cells are of this type, being successful revolutionists against the organotypical control.

There seems little doubt that Minot's position is untenable in this respect, except possibly for some of the most highly differentiated cells in the highest animals. The results of regeneration experiments in the lower animals (Child, 1913), and the recent successes in growing animal tissues in plasma (Carrel and Burroughs, 1910, Carrel, 1912, and others), seem to show conclusively that specialized tissue has not irretrievably lost its earlier powers.

For forty years the evidence from the plant side has been amply sufficient to show that Minot's views as to the irreversibility of differentiation would

not hold for plant cells (Nemec, 1905). The formation of adventitious tissue, of secondary meristems, of budding and mature leaves, has shown the possibility of de-differentiation in specialized plant cells.

The writer's results attack Minot's theory in an even more vital point, since they indicate that senility occurs even in meristematic tissue and is not dependent on differentiation. Furthermore, Minot's own figures regarding the relative rapidity of the advance of senile degeneration, showing that its onset is most rapid at the very beginning, when differentiation is least, argues against the theory that specialization is the primary cause of senility.

Accumulation of katabolic products

Child (1912), in an extremely interesting paper, states his opinion as follows: "My experiments led me to the conclusion that senescence in its simplest terms consists in a decrease in the rate of metabolism determined by the gradual accumulation of relatively inactive structural obstacles to metabolism which in turn are the necessary consequence of continued metabolism under constant or relatively constant conditions and in the presence of nutritive material."

Hertwig, from his study of the "depression stages" in various protozoa, comes to the conclusion that senescence is due to the accumulation of materials in the nucleus until it becomes inert. He considers that a large amount of material must be eliminated from such an engorged nucleus before it can again become active. Child (1913), from his study of a planarian, which reproduces only asexually, and from a long series of regeneration experiments, has come to the conclusion that when such an accumulation occurs a condition of senility is reached, and rejuvenescence is restored only if the cell can rid itself of the accumulated inert substances. He is of the opinion, further, that hunger, removal of a part of the body, encystment, and asexual reproduction, are as efficient in this respect as sexual reproduction. He says, as regards the plants, there can be no doubt that the same is true.

Hertwig (1906) disagrees in part with this conclusion. He thinks that hunger, encystment, and special protozoan methods of nuclear destruction, are temporary patchwork repairs which, in forms capable of sexual reproduction, postpone senility but cannot produce the complete rejuvenescence that results from sexual reproduction. The evidence obtained from

the studies on *Vitis vulpina* supports the view of Hertwig and disapproves Child's statement regarding certain plants at least. In forms that are without sexual reproduction and that are capable of continuous existence, the protoplasm must free itself from its accumulations more readily than protoplasm that depends on sexual reproduction.

It will be noticed that both Hertwig and Child picture the accumulation of inert products as interfering primarily with metabolism as a whole, not merely with katabolism. This accumulation theory must be discussed, as to its probability, in connection with the next theory of senility.

Decreased elimination of waste products

The first thorough treatment of the idea that senility may be due to the retention of poisonous waste in the tissues was that by Mühlmann (1900). His argument is based on the fact that as the growth of a many-celled organism goes on, the central cells are shut off from direct contact with oxygen, and become dependent for food, oxygen, and elimination of waste on the cells that still remain in contact with the surface. With increased growth, moreover, the mass increases as the cube, while the surface increases only as the square, of the dimensions. Therefore the number of dependent cells is increasing much more rapidly than the number of those cells that are able to excrete. The central cells are thus forced to retain their poisonous waste products longer and longer, and suffer in consequence an increasing degree of poisoning. Mühlmann makes the interesting observation that the organs which represent the surface continue to grow for the longest time — skin, lungs, intestines, vessels, and heart, which grow for from forty to fifty years after birth; while the musculature and the skeleton, which lie deeper in the body, stop their growth earlier, and the nervous system, which is deepest of all, grows but little after birth.

Montgomery (1906) gives an interesting argument along the same line. He says that death results from the insufficiency of the excretion process, and that this becomes impaired because the excreting surfaces do not keep pace with the increase in mass. He carries this idea so far as to postulate that spore formation and gamete production are essentially excretion processes, the spores or the gametes separating from the poisoned excrementitious soma. He exactly reverses the old Hildebrand and Weismann concept that the soma dies because the gametes have been produced and

have gone, by claiming that the sex cells left because they could not endure the conditions any longer.

There are some very serious objections to be raised against the argument that harmful retention of waste products, due to the greater increase of mass than of surface, is the basic cause of senility. Considering first the condition in the human being, it is seen that the excretory surfaces continue to grow until the period of greatest activity is well past. Why should the excretory surfaces, which proved amply sufficient during the period of greatest activity, be unable to do their part after the organism as a whole is much less active?

Furthermore, if the amount of surface of the excretory organs is not sufficient to eliminate waste products fast enough for the internal mass of cells to continue to be active, how can be explained the rapid development of the unborn child, which must depend on its mother's excretory surfaces to eliminate not only her own tissues' waste but its own as well. It should be borne in mind that many of the human organs have a considerable excess power above that which is needed for ordinary excretions, and there are many evidences to show that the excretory organs can eliminate much more than they are usually called upon to do.

In this theory of the insufficiency of excretion, the "guilty-organ" theory is being met under a different form. It is not a single organ, but a single function, which is at fault this time.

When this theory of the insufficiency of excretion produced by the disproportionate increase in surface and mass is examined in the light of the facts reported for Vitis, important evidence against it is seen at once. In the perennial vine with its annually increasing number of leaves, there is no such discrepancy between increase in surface and mass as is found in animals, and yet here, as in animals, comes this same senile degeneration. If, therefore, there is a retention of harmful waste products in cells, it is not due to the apparently plausible disproportionate increase of volume and surface.

The retention of poisonous waste material, however, should be considered as important among the different possible causes of senility, as affecting the active cell. The immediate harm suffered by the human body from the lack of a pound of food is very much less than that which could be caused by the presence in the body of a minute quantity of poison. In other words, equal losses in efficiency in the functions of digestion and

excretion may not be of equal harm to the cell. The loss in efficiency of excretion will affect the cell first. This is the argument which supports the idea that defective excretion may be the cause of senility, rather than the argument based on relative surface and mass.

But here again, if the efficiency of excretion becomes lessened, it must be due to some chemical or physical change occurring in the cell, and this change must then be the primary senile deterioration of which the decrease in excretion is a result.

A change of this nature seems to be indicated in the cells of the leaves of *Vitis vulpina* and certain other plants. A change in permeability, which would explain the decrease in size of the vein islets if present in all living cells, both plant and animal, would directly and inevitably decrease the efficiency of excretion of all cells both internal and external.

DECREASING PERMEABILITY AS AN EXPLANATION OF SOME OBSERVED SENILE DEGENERATIONS

It should be emphasized at this point that a decrease in permeability with age must be the result of some deeper-lying physical or chemical senile degeneration in protoplasm. It is probable that this fundamental cause produces other changes besides that of decreasing permeability. This will be touched upon shortly. With this in mind, it will be interesting to see to what degree a senile decrease in permeability will produce the effects which the other theories of senility assert are present and which they explain in their own way.

The presence of inert accumulations in cells would certainly be brought about by an increasing difficulty of exit from the cells. Furthermore, it is quite possible that decreasing permeability would favor the production of changed metabolic products. It is equally evident that a certain degree of impermeability is also essential to the cell, since on this depend the retention of food, the protection against harmful solutes in the environment, and the maintenance of turgidity. There must therefore be a constant compromise in the living cell between permeability and complete impermeability. It is possible that even in the youngest and most vigorous cell the degree of permeability required is such that oxygen cannot enter as rapidly as is needed at times of great activity. Under such partially anaërobic conditions, it is well known that certain cells, bacteria for example, may produce different katabolic products from those produced

when abundant oxygen is available. Some of these products might be such as would merely interfere with cell activities by their accumulation, while others might be toxic in their action. It is quite possible that some of these changed products resulting from incomplete permeability might act upon the protoplasm in such a way as to further decrease its permeability. This would lead in turn to a more rapid production of the injurious substances. The presence of a decrease in permeability with age seems to account in part for the retention of inert accumulations, and possibly may be considered an important cause for the production of the accumulating material. It is interesting to note that this idea had occurred to Child (1912) in connection with senile degeneration in sperm cells, although he did not consider it as a general cause of senility.

The objections which may be raised against the theory that senility is due to the retention of toxic waste products owing to the lack of sufficient excretory surfaces in old organisms, do not apply when the retention of these substances is referred to a general decrease in permeability operating in all cells of the organism. A decrease in permeability as age increases accounts perfectly for every condition that the older theory claimed to exist. The loss of efficiency in excretion will occur in small organisms as certainly as in large ones, will characterize all cells and not simply a localized fraction, and does not require any postulates regarding relations between mass and surface, which are certainly untenable for the higher plants and probably for the higher animals. Furthermore, increasing permeability interferes with the inward movement of substances, and this undoubtedly is also an important consideration and perhaps in plants more important than difficulty of excretion.

Lillie (1909) argues strongly that many stimuli act on cells by the production of temporary increases in their permeability. It is also obvious that a complete cessation from activity tends to aid in the elimination of substances from the cells. Since the production of new metabolic products ceases, the cell is able to get rid of a certain amount of accumulated waste. Hunger, sleep, the division of the lower animals in regeneration experiments, encystment, and asexual reproduction, would therefore, in varying degrees according to method and organism and environment, utilize both these methods for decreasing the accumulations. The internal stimuli which are set in force in starvation effect katabolism

of storage products that under normal conditions are unaffected, and in such cases the nature of the stimulus may also be such as to increase the permeability of the cells.

In the form in which no sexual reproduction occurs, it is possible that the accumulation of products resulting from the decrease in permeability, when it reaches a certain stage, produces a stimulus of such powerful nature that the original degree of permeability is restored. It is noteworthy, in this particular, that passive stages or encystment are common in such forms and aid in the process of waste elimination.

Is there any reason to believe that sexual reproduction rejuvenates through a restoration of the original degree of permeability? If senility is due in part to decreasing permeability, then rejuvenescence must be due in the same degree to increased permeability.

The effects of sexual reproduction can be most easily studied in the eggs of marine forms, which are normally fertilized when free in the water. A considerable number of researches on such material have been made by animal physiologists, and among the functions studied was this one of permeability. All these investigators have described a marked increase in permeability as the most characteristic effect of the entrance of the sperm into the ovum. This union of the two sex cells, therefore, generates a stimulus of such a powerful influence on permeability that the original degree of permeability is restored. Lillie (1909) has observed that pigments present begin to pass out rapidly; Lyon and Shackell (1910) found that dyes entered much more readily than before; while Loeb (1907), Warburg (1910), and others have observed that oxygen entered much more rapidly than before. Lillie (1909) thinks that this first remarkable increase in permeability lessens to a certain degree soon after; but this, if true, merely means that the first great increase in permeability is even greater than that characteristic of youth — one that is valuable for the sudden expulsion of accumulated waste, but too great to be suited for the retention of food, for turgidity, and for protection in the living embryo.

The evidence seems strong, therefore, both from the standpoint of senility and from that of rejuvenescence, that the duration of life is directly linked with the degree of permeability in that part of the living cell which places it in contact with the universe about it, and that as the activities of life

proceed the cell is being gradually entombed by an inevitable decrease in the permeability of its protoplasm.

While decreasing permeability furnishes a possible explanation of the more obvious symptoms of senility, it cannot be the only degeneration of first rank. All protoplasmic functions must be involved. Underlying these primary causes of senile degeneration there must be some general fundamental cause from which they spring. This fundamental cause may well be the colloidal nature of protoplasm. While the physical attributes that characterize the colloidal condition of matter are not thoroughly understood, the crude generalization may perhaps be advanced that the unit of structure of the colloid is a molecular complex while that of the crystalloid is a single molecule. The physical changes which colloids undergo when exposed to external forces may be referred to rearrangements in the positions of the molecules in the unit complexes. The rise of the melting point of paraffin on repeated applications of heat, the reversible or irreversible changes from sol to gel under different degrees of heat, and other modifications of colloidal response produced by repeated applications of a given force, are examples of colloidal changes probably due to rearrangement of the molecules in the complex.

This intricate interrelation between the constituent parts of the colloidal unit of structure is subject to progressive changes in many non-living colloids, and these, with the passage of time, exhibit changes which might be called senile degenerations. The tendency to a closer approximation of the units of colloidal suspensions, as time goes on, is an illustration of the instability of the colloidal condition. Since the relatively simple relations in the nonliving colloidal complex tend to change on the application of external forces, or even with long standing, it seems inevitable that the extremely complex colloidal states constituting protoplasm should be progressively modified by the activities of life and the impact of external forces. The wonder is not that protoplasm is subject to senile change, but that the change is so slow.

If one of the changes in the colloidal units is a closer aggregation of the constituent parts, the probable effect on protoplasm will be to make it less permeable, lessen the quantity of imbibed water, and obstruct the other physical activities of life. Whatever the changes in the colloidal complex may be, they are the fundamental cause of senility.

Rejuvenescence is the process of restoring the original arrangement in the colloidal units of the protoplasmic colloids. Sexual reproduction is one method by which this is accomplished, while in sexless plants more primitive methods are used.

Whether the progress of senility in sexual plants and animals can be stopped, or even retarded, by such means of rejuvenescence as are utilized in sexless forms, and thus to a certain degree are applicable to somatic cells generally, is a problem for the future to solve. The present knowledge of the cause of senile degeneration does not justify an unqualified denial of the possibility of somatic rejuvenescence.

ACKNOWLEDGMENTS

The writer takes pleasure in expressing his indebtedness to Dr. Lewis Knudson, of Cornell University, and to Dr. B. M. Duggar, of the Missouri Botanical Garden, for many valuable suggestions in the preparation of this paper. He also acknowledges the leave of absence granted to him by his own institution, the University of Cincinnati, which enabled him to hasten the completion of this stage of the work.

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A BACTERIAL DISEASE OF STONE FRUITS

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A BACTERIAL DISEASE OF STONE FRUITS

A BACTERIAL DISEASE OF STONE FRUITS[1]

F. M. Rolfs

HOST CONSIDERATIONS

Cultivated varieties of the apricot (*Prunus armeniaca*), the nectarine (*Prunus persica* var. *necturina*), the peach (*Prunus persica*), and the plum (*Prunus domestica*, *Prunus americana*, and others), are known to be affected by the bacterial disease discussed herein. It will be noted that the hosts are closely related.

THE DISEASE

NAMES

The disease on the foliage during its early development or in cases of slight infection is known as *bacterial leaf spot;* in more advanced stages or in more serious outbreaks it is termed *bacterial shot hole.* On the fruit it is sometimes referred to as *black spot*, the growers, however, more commonly speaking of it as *bacterial crack.* The disease on the young twigs has received the names *black spot* and *black tip*, and when open perennial wounds are formed on the branches these are called *bacterial cankers.*

HISTORICAL

The disease is apparently of American origin, it having been found, so far as is known, only in the United States. During the past nine or ten years fruit growers in various sections of the country have called attention to a shot-hole disease of peach and plum foliage, which in wet seasons has in many cases caused premature defoliation. O'Gara (Rorer, 1909)[2] reports a shot-hole condition of peach foliage prevalent in Georgia, and suggests that it is caused by a bacterial organism. Smith (1903) calls attention to a bacterial disease of Japanese varieties of plum in central Michigan, which appears as a shot hole of the leaves and a black spot of the fruit. Clinton (1904) describes a leaf spot on peach in Connecticut, which he attributes to a bacterial organism. Heald (1906) discusses a disease, apparently of the same nature, found in Nebraska on the twigs

[1] Also presented to the Faculty of the Graduate School of Cornell University, June, 1913, as a major thesis in partial fulfillment of the requirements for the degree of doctor of philosophy.

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[2] Dates refer to literature cited, page 431.

and branches of Wickson and Whitaker varieties of plum. Jackson (1907) reports a similar disease from Delaware, and states that considerable injury results to the plum orchards in that State. Smith (1905 b, figs. 11, 12, 15, 70, 72, pl. 19) gives diagrams of sections through diseased plum leaves and fruit tissue, and illustrations of diseased plum fruit. Rorer (1909) records a detailed study of the disease on leaves, twigs, and fruits of peach. Smith (1911) discusses the disease on plum leaves and fruits, and gives illustrations of diseased plum fruits as well as sections through diseased fruit tissue. Heald and Wolf (1912) report the occurrence of a bacterial canker on plum at San Antonio, Texas. Lewis (1912) describes a bacterial canker on plum twigs and records the results of several inoculation experiments. He gives illustrations of cankers on twigs four and six years of age.

The disease was first brought to the attention of the writer in 1904, when he was Botanist and Horticulturist at the University of Florida. Many letters were received from fruit growers in northern Florida and southern Georgia, complaining of a shot-hole condition of peach and plum leaves accompanied by considerable premature defoliation. The foliage of the different varieties of peach and plum trees in the university horticultural orchard also developed the shot-hole condition, and in most cases fell prematurely. Other duties prevented the writer from undertaking extensive investigation of the problem at that time. However, on taking up work at the Missouri State Fruit Experiment Station in 1906, he found that the blackened areas, so common on the peach twigs in northern Florida in 1905, were even more abundant on the peach and plum twigs in Missouri. Additional observations have brought out the fact that the disease is more or less injurious also to the apricot and the nectarine.

GEOGRAPHICAL DISTRIBUTION

It is not easy to obtain information as to the distribution of this disease, since a bibliography of the literature relating to shot-hole injury of stone fruits shows that the injury is usually attributed to the work of fungi. This is not surprising, as lesions resulting from various causes resemble one another so closely that it is often impossible to determine exactly the causal factor without the aid of a microscope, and it is not always possible even with a microscope. The disease has been reported by investigators as occurring in Arkansas, Connecticut, Delaware, Georgia,

Michigan, Nebraska, and Texas. Diseased material has been obtained by the writer from Alabama, Arkansas, Florida, Georgia, Illinois, Iowa, Kansas, Michigan, Missouri, New Jersey, New York, Ohio, Oklahoma, Pennsylvania, South Carolina, Tennessee, and Texas.

ECONOMIC IMPORTANCE

Bacterial leaf spot, or shot-hole as it is usually called, is one of the chief foliage diseases of stone fruits in the humid districts of the South. It occasionally becomes more or less aggressive also in some sections of the northern and eastern States. Its importance varies from year to year, there being an abundance in wet seasons and little in dry seasons. The disease appears to be more severe in warm, humid regions than in cool, dry sections. In southern Missouri its economic importance has kept pace with the growth of the peach industry, and it is now one of the most difficult diseases with which the fruit grower has to contend. Its attacks on the plum have made it practically impossible to grow certain varieties of Japanese plums on a commercial scale. The fruit of some varieties of apricot and nectarine also are injured more or less by the disease, but since apricots and nectarines are not extensively grown in Missouri the disease on these fruits has not attracted much attention.

In different parts of Missouri, during 1908 and 1909, a record was made of the amount of infected fruit in diseased Elberta peach orchards, in order to determine the extent of the injury due to this disease. It was found that from 1 to 10 per cent of the fruit was infected in orchards well cared for, and from 25 to 75 per cent in orchards poorly cared for. The lesions on the fruit are in many cases not sufficiently prominent to mar its appearance greatly, but the larger proportion of such fruit is graded as "seconds." None of the fruit holds up well in shipping, and in some cases it is completely destroyed by various rot-producing organisms before being placed on the market.

It is especially difficult to obtain reliable figures on the loss due to this disease, since the loss is not confined to the direct effect on the fruit but must include also the influence of the diseased foliage on the general vigor of the tree. Severe outbreaks soon impair the efficiency of the foliage, and if they occur early in the season they reduce the size and greatly lower the quality of the fruit. Severe foliage injury also has a marked influence on the formation of fruit buds, and trees that have their leaves

injured early in the season usually carry a very light crop of fruit the following year. Young trees are usually more affected than those six or seven years old, and badly diseased young trees soon become stunted and in some cases permanently injured.

SYMPTOMS

The disease affects the leaves, twigs, and fruit in a characteristic manner. It develops on twigs and shoots of only the current year's growth, but the wounds on the twigs often persist as open perennial cankers.

The very common fungous disease of apricot and plum foliage due to *Cylindrosporium padi* is similar in its symptoms to bacterial leaf spot, but usually can be distinguished from the latter by the white downy growth on the lower surface of the spot. Pierce (1894) reports a similar disease on almond foliage in California due to the work of *Cercospora circumscissa*. There is also a leaf spot of unknown cause which is constantly associated with peach and plum rosette. Spray mixtures and other toxic substances applied to the leaves often produce an injury which is difficult, without the aid of a microscope, to distinguish from bacterial leaf spot. Care must be taken not to confuse the lesions due to these various agents.

On the leaves

The first evidence of the disease on the leaves is the appearance of small gray specks (Fig. 59), which become somewhat angular in form and soon take on a water-soaked appearance. They later become brown or purplish brown, in some cases scarlet, and finally change to dark brown. The spots measure from one to five millimeters in diameter and when numerous they coalesce, so that large areas of the leaf may be involved. A more or less circular diseased area is finally separated by a line of cleavage from the healthy tissue, the injured tissue within this area promptly contracting, drying, and falling out. This gives the leaf the shot-hole appearance. On the plum, in some cases, after the disease has apparently run its course and the spot is well formed, a second and even a third period of invasion may follow and an area one-half inch or more in diameter may develop from a single spot. Leaves that are badly diseased soon fall to the ground. It is not unusual for an infected tree to lose from fifteen to twenty-five per cent of its leaves by August, and in the more extreme cases as high as seventy-five per cent, or even more, of the leaves

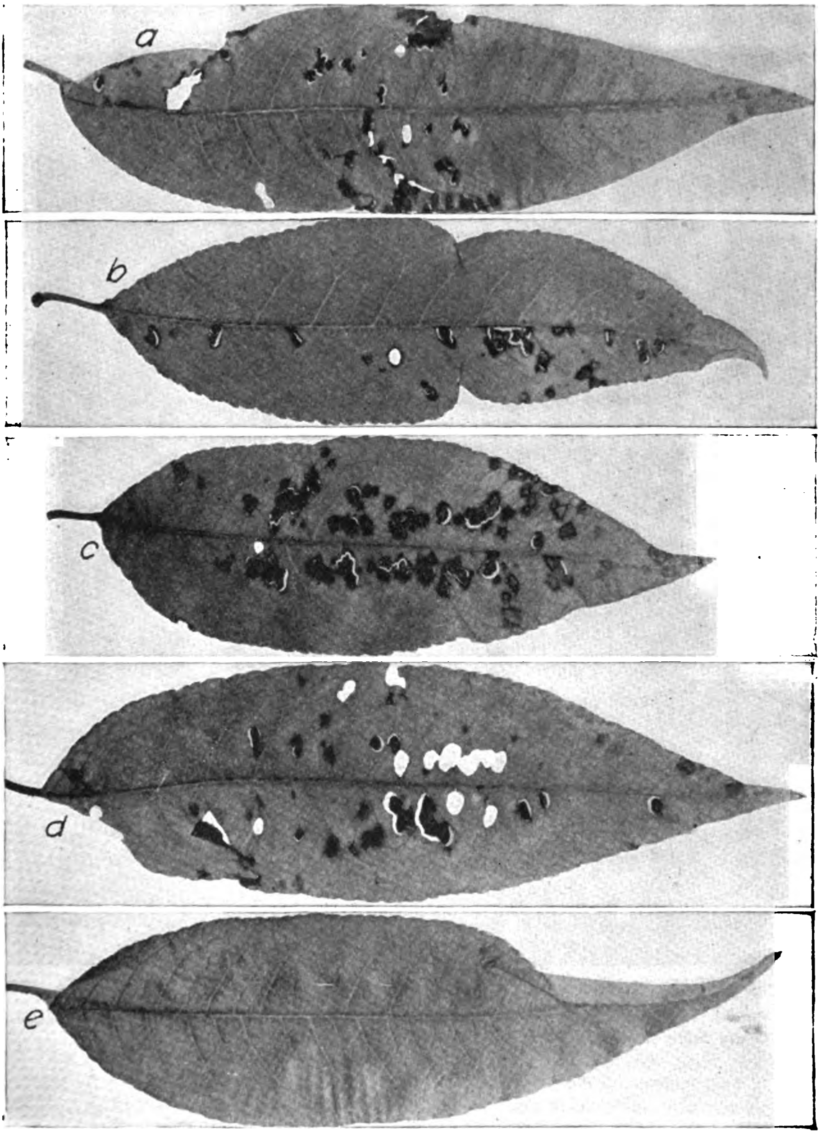

FIG. 59.—*Elberta peach leaves inoculated with pure cultures of Bacterium Pruni. The growth from a seven-days-old-slant Hiss-glucose culture was thoroughly mixed in one hundred cubic centimeters of sterile water and applied to the leaves by dipping the fingers into the water and then rubbing the leaf between the thumb and the fingers. Inoculations were made on July 16, 1912, and the photograph was taken on August 28, 1912*

a, Inoculated with a pure culture obtained from an apricot twig
b, Inoculated with a pure culture obtained from a nectarine twig
c, Inoculated with a pure culture obtained from a peach twig
d, Inoculated with a pure culture obtained from a plum twig
e, Check. Sterile water was applied to the leaf

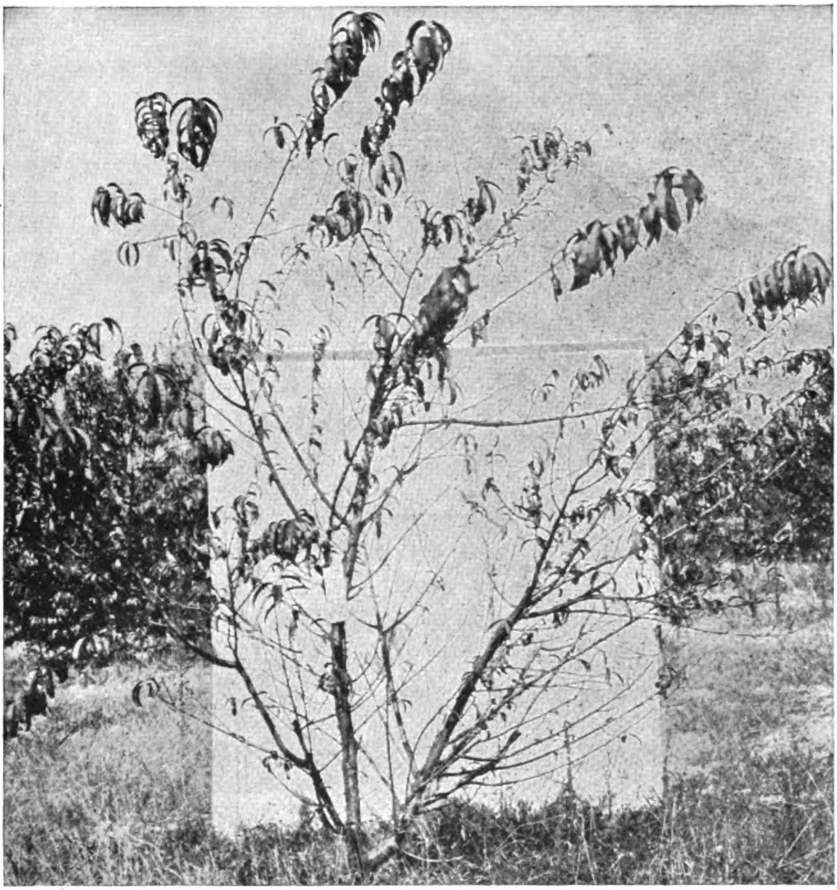

FIG. 60.—*Arp Beauty peach tree showing defoliation due to the work of Bacterium Pruni. Most of the leaves that formed before July 1, 1909, have fallen. All leaves still on the tree are more or less injured. (Photograph made on September 6, 1909)*

FIG. 61.—*Elberta peach twigs inoculated with pure cultures of Bacterium Pruni. The growth from an eight-days-old-slant Hiss-glucose culture was thoroughly mixed in one hundred cubic centimeters of sterile water. Each twig was inoculated at four points by inserting the point of a hypodermic needle just below the cuticle and forcing the water containing the organism into the tissues. Inoculations were made on June 25, 1912, and the photograph was taken on August 20, 1912*

a. Check. Sterile water was used
b and c, Inoculated with a pure culture obtained from an apricot twig
d, Inoculated with a pure culture obtained from a nectarine twig
e, Inoculated with a pure culture obtained from a peach twig
f, Inoculated with a pure culture obtained from a plum twig

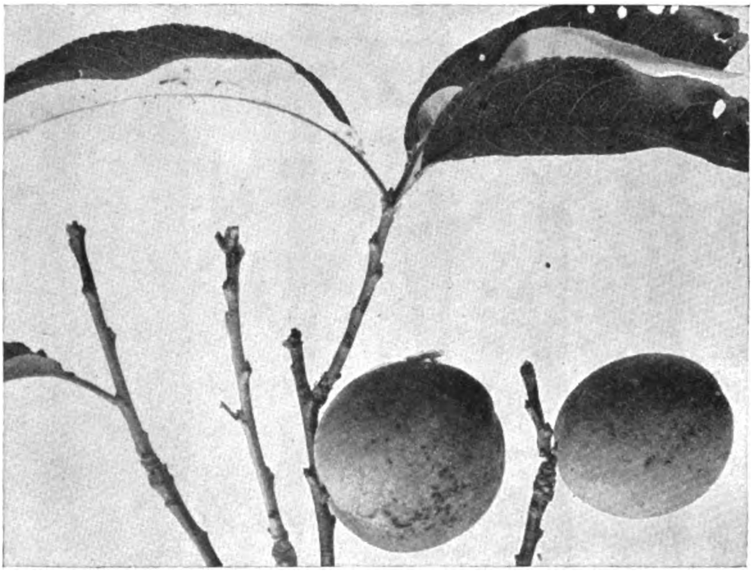

Fig. 62.—*Elberta peach twigs, leaves, and fruit, showing injury by Bacterium Pruni. The black tips of the twigs are to be noted particularly.* (*Photograph made on August 15, 1909*)

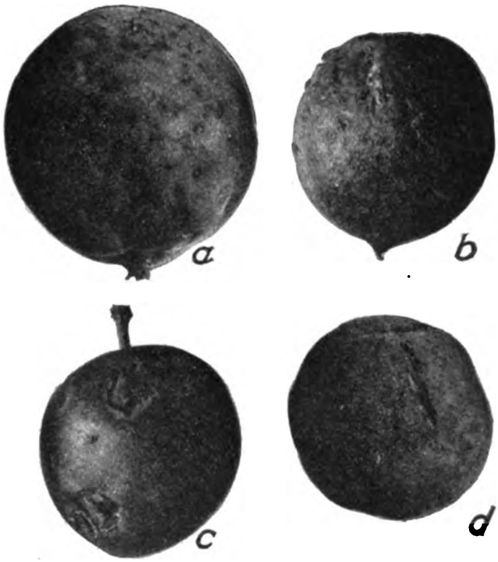

FIG. 63.— *Naturally infected fruits of peach, nectarine, plum, and apricot: a, Crothier peach; b, Victoria nectarine; c, Abundance plum; d, Bread apricot. (Photograph made on July 1, 1909)*

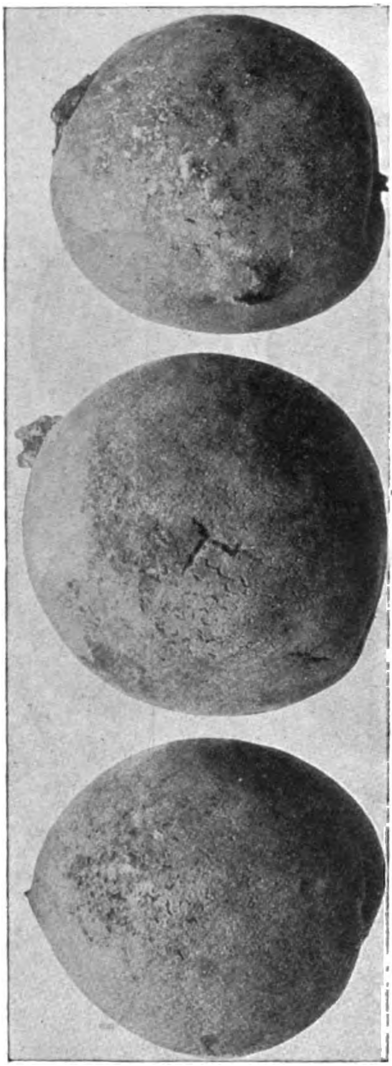

FIG. 64.—Elberta peach fruit showing injury by Bacterium Pruni. The tree was sprayed seven times. The first application was made with lime-sulfur solution, 15-15-50 formula, on March 12, shortly before the fruit buds had opened. The other six applications were made with self-boiled lime-sulfur mixture, 12-8-50 formula. The first of these applications was made on April 21, just after the leaf buds opened; the others followed at intervals of about twelve days. Fifty-two per cent of the fruit was dotted with numerous cracks. (Photograph made on August 12, 1908)

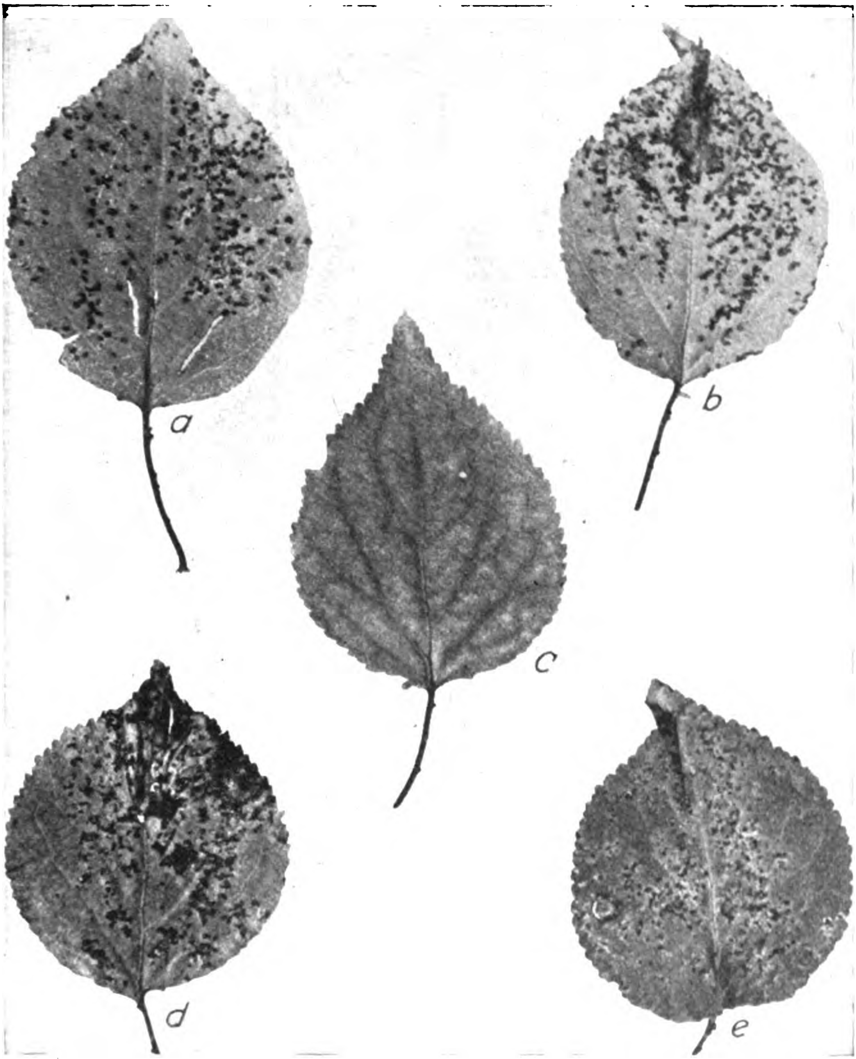

FIG. 65.—*Alexander apricot leaves inoculated with pure cultures of Bacterium Pruni. The growth from a six-days-old-slant Hiss-glucose culture was thoroughly mixed in one hundred cubic centimeters of sterile water and then applied to the leaves by dipping the fingers into the water and gently rubbing the leaves between thumb and fingers. Inoculations were made on June 29, 1912, and the photograph was made on August 27, 1912*

a, Inoculated with a pure culture obtained from an apricot twig
b, Inoculated with a pure culture obtained from a nectarine twig
c, Check. Sterile water was applied to the leaves
d, Inoculated with a pure culture obtained from a peach twig
e, Inoculated with a pure culture obtained from a plum twig

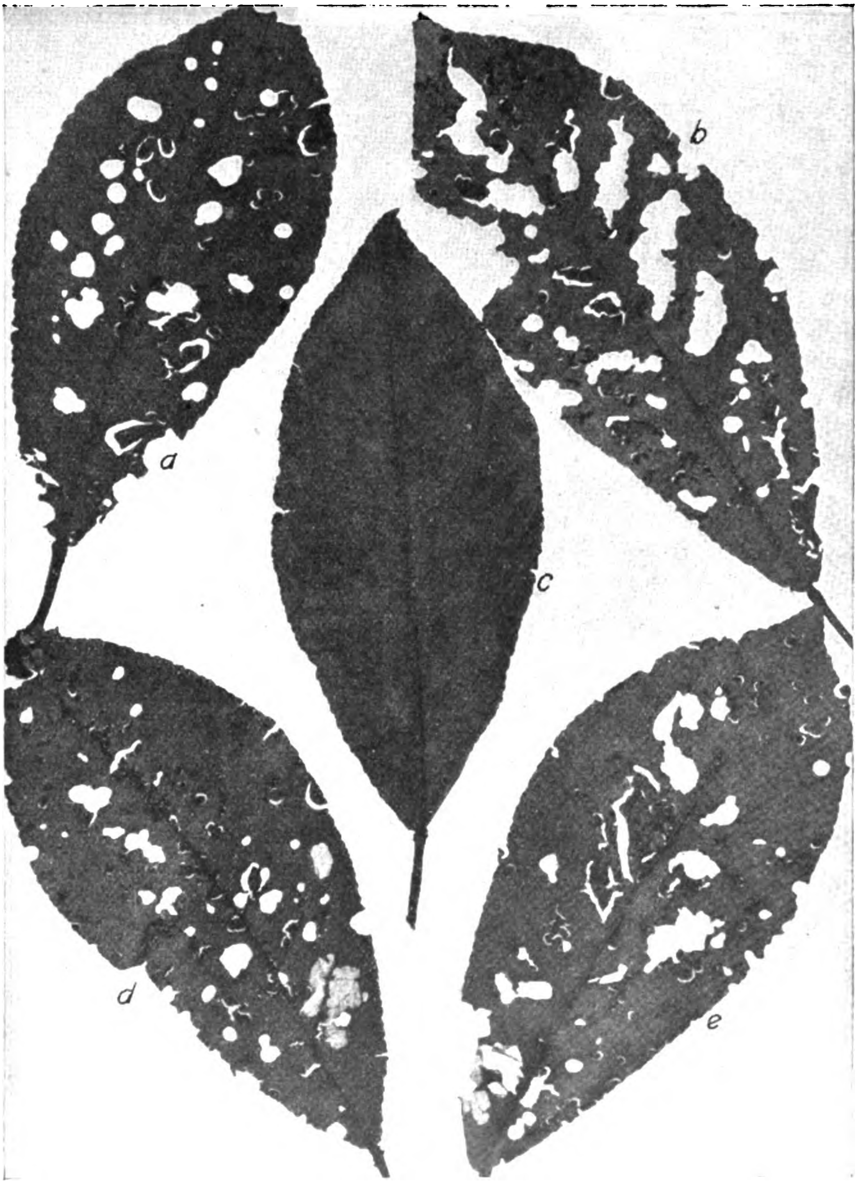

FIG. 66.— *Burbank plum leaves inoculated with pure cultures of Bacterium Pruni. The growth from a seven-days-old-slant Hiss-glucose culture was thoroughly mixed in one hundred cubic centimeters of sterile water and applied to the leaves by dipping the fingers into the water and then gently rubbing the leaves between thumb and fingers. Inoculations were made on June 27, 1912, and the photograph was made on August 27, 1912*

a, Inoculated with a pure culture obtained from an apricot twig
b, Inoculated with a pure culture obtained from a nectarine twig
c, Check. Sterile water was applied to the leaves
d, Inoculated with a pure culture obtained from a peach twig
e, Inoculated with a pure culture obtained from a plum twig

fall. The older, first infected leaves are usually, although not always, the first to go. One leaf after another falls, leaving finally only a tuft of young leaves at the tip of each twig and giving the tree a characteristic appearance (Fig. 60).

On the twigs

In some seasons black cankers form on the twigs in early spring, but as a rule these do not appear in abundance until May or June. The first visible indication of the canker is the appearance on the young shoots of a water-soaked spot surrounding a lenticel. In some cases the diseased area bulges out, more or less, in the beginning. As the spot enlarges it soon elongates. Single spots measure from one to four centimeters in length and often extend from one-half to two-thirds of the way around the shoot. The area becomes more or less sunken in age, soon becomes brown or purplish brown, then dark brown, and finally purplish black or black (Fig. 61). It frequently happens, especially on the nectarine and the peach, that several of the spots become confluent, forming areas which extend from two to three inches along the stem and in some cases completely girdle it. In favorable seasons the tips of many of the shoots are entirely blackened and killed (Fig. 62), this condition being most prominent on the nectarine and the peach. In most cases the injury is overcome gradually, and as a rule all traces of these black cankerous spots disappear in the second year.

The black spots on apricot twigs also disappear for the most part, but on plum twigs many of them persist from year to year, forming perennial cankers. As many as twenty-two cankers in different stages of development have been counted on a single plum twig (a water sprout). Open cankers also form on the apricot, the nectarine, and the peach, but they are far less abundant on these trees than on the plum.

The disease is usually more aggressive during the first two or three years after planting than it is later. It is not only likely to defoliate the young trees prematurely, but in many instances it kills back the twigs and frequently stunts the trees. A case of this sort was under observation, in which two hundred Elberta peach trees from an infected nursery were mixed with a shipment of twenty-three thousand healthy trees. Within three years from the time of planting, every tree in the orchard was more or less diseased, and many of the trees remained small and produced small, inferior fruit.

On the fruit

The disease does not ordinarily appear on the fruit until about the middle of May. Injured fruits of all the four kinds of hosts, however, have been collected early in May (Fig. 63). The first external signs of the disease are numerous small gray specks just below the cuticle. These specks enlarge slightly and soon take on a water-soaked appearance or a purplish color. The skin over the spots is soon ruptured, producing numerous straight or angular cracks which resemble the wounds on chapped hands (Fig. 64). Usually individual spots do not measure much more than two millimeters in diameter, but they are often so numerous that the cracks soon become confluent and frequently form a network, fissures nearly an inch in length being developed in some cases. On young growing fruit it is not uncommon to find rifts extending nearly the entire length of the fruit. Such wounds mar its appearance and in many cases render it worthless for market.

On all kinds of fruit the disease results in the formation of these small, more or less abundant, crack-like wounds, but certain varieties of the nectarine are especially liable to this type of injury. In some cases the spots gradually widen and extend for a considerable depth into the tissue, forming roundish, sunken, black spots which finally measure from one-fourth to one-half inch in diameter. Rifts develop in the blackened tissue. These widen, and cracks appear throughout the diseased area which often (especially when the disease is on young developing fruit) finally extend beyond the dead into the healthy tissue. In many cases the fruit becomes so badly distorted and cracked that it is worthless, and it is soon destroyed by various rot-producing organisms.

ETIOLOGY

Historical

The pathogen causing this disease was first isolated by the writer in 1904 at the University of Florida. Many poured plate cultures were made from the spots on injured leaves of both peach and plum. Cultures made from the young water-soaked spots invariably gave numerous yellow bacterial colonies, and in no case was a species of Cercospora or Cylindrosporium obtained. Consequently it was concluded that the disease was of bacterial origin. It was observed also that the defoliated

twigs sometimes showed one or more blackened, slightly sunken areas. These often measured as much as seven millimeters in width and extended from five to fifty millimeters along the stem, in some cases the entire end of the twig being blackened. Cultures from these areas produced yellow bacterial colonies.

On taking up work at the Missouri State Fruit Experiment Station in 1906, the writer observed that the twigs of some varieties of peach and plum in Missouri also showed blackened, sunken areas, and poured plate cultures from the diseased tissue in many cases gave yellow bacterial colonies. About the middle of June, 1906, it was observed that the foliage of trees bearing the diseased twigs had developed the shot-hole condition to a marked extent, while the foliage on trees with twigs free from the blackened areas was quite free from shot-hole. The fruit on Abundance and Burbank plum soon developed many typical black-spot areas, from which pure cultures of a yellow organism were easily obtained. A little later many peach fruits developed numerous small cracks. These were at first supposed to be due to the work of curculio, but a careful examination showed bacteria to be present in enormous numbers.

A careful study soon proved that the organism had invaded the apricot and the nectarine in much the same way as it had the peach and the plum. The fruit of the nectarine in the station variety orchard in 1906 was so badly cracked as a result of the attack of this organism that the entire crop was destroyed by various decay organisms long before the ripening period. Some of the apricot fruits developed the typical black spot. The twig cankers on both apricot and nectarine were fully as plentiful as on the peach, and premature defoliation also occurred on both apricot and nectarine trees.

Nomenclature

Since bacteriologists have not yet adopted an international code of nomenclature, it does not seem advisable to enter here into an extended discussion of the limits of genera, the selection of types, or the position of this organism in the various systems of classification proposed. The writer has therefore elected to follow arbitrarily the suggestion given by Erwin F. Smith (1905a). The organism was first described by Smith (1903) under the name *Pseudomonas Pruni*. Later, however, it became *Bacterium Pruni*, when Smith substituted the generic name Bacterium Cohn emend. for Pseudomonas Migula.

Pathogenicity

Conclusive proof of the pathogenic nature of this organism was obtained in 1904 by Smith (1905 a), by inoculating the foliage and the fruit of Abundance plum. The pure culture of the organism used in inoculation was obtained from plum fruit of the same variety. The organism from several young-slant agar cultures was scraped into two hundred cubic centimeters of sterile water and sprayed with an atomizer on the foliage and fruit of a five-years-old tree. Diseased spots developed on both leaves and fruit in from ten to twelve days and became numerous after fourteen days. Poured plates from the fruit and the leaves of the inoculated trees yielded numerous colonies of the yellow organism. In 1907 Smith (1908) also successfully inoculated the foliage of a peach tree with the plum organism. Rorer (1909) isolated the organism from peach leaves in 1906, and the following year made a series of successful inoculations with it on the foliage of Elberta peach trees at Bentonville, Arkansas. His results agree in every way with those obtained by Smith with the plum organism. Rorer also obtained pure cultures of the organism from peach twigs and reported its occurrence on peach fruit. He found the cultural characters of the plum and peach organisms to be exactly the same.

In 1907, at Mountain Grove, Missouri, the writer repeated and confirmed Smith's experiments on the plum, and extended the infection experiments to apricot, nectarine, and peach. The organism used was isolated from an Abundance plum fruit and grown in pure culture. The organism was scraped from several slant agar cultures into one hundred cubic centimeters of sterile water, and sprayed with an atomizer on the fruit and leaves of eight-years-old trees of Royal apricot, Victoria nectarine, Elberta peach, and Abundance plum. The inoculations were made during a light, drizzling rain. Disease spots developed on fruit and leaves of all four hosts within twelve days, and after fifteen days they became very numerous. Poured plates from the fruit and the leaves of the inoculated trees yielded numerous colonies of the yellow organism. However, several of the check leaves on the apricot and the nectarine trees also developed spots from which the yellow organism was obtained. Pure cultures of the organism were obtained by the writer from leaves and twigs of apricot, nectarine, peach, and plum. These strains and the one obtained from an Abundance plum fruit were grown side by side on various culture media, and were exactly alike in all cultural characters.

In 1909, at Mountain Grove, cross inoculations with the four strains obtained from the leaves were made on eight-years-old Royal apricot, Victoria nectarine, Elberta peach, and Abundance plum trees. Two hundred leaves, fifty fruits, and twenty twigs were used in each case. The organism from young-slant Hiss-glucose cultures was thoroughly mixed with sterile water and sprayed on the leaves and the fruit with an atomizer. Each of the twenty twigs was inoculated at four points with a hypodermic syringe. Spots appeared on the leaves of all the inoculated trees in ten days, and on the fruit in from twelve to fifteen days. The inoculated tissue on the twigs assumed a water-soaked appearance in from four to eight days, becoming dark brown and finally, in about twenty-five days, almost black. Poured plate cultures from the spots on leaves, fruit, and twigs yielded numerous colonies of the yellow organism. Three of the check leaves on peach also developed a number of brown spots.

In 1910, at Mountain Grove, cross inoculations with strains of the organism from the fruit of the four hosts were made on eight-years-old Royal apricot, Victoria nectarine, Elberta peach, and Burbank plum trees. Fifty leaves and ten twigs were used in each case. The organism from young-slant Hiss-glucose cultures was scraped into sterile water. The fingers were dipped into this water, and the material was applied to the lower surface of the leaf by gently rubbing the leaf between thumb and fingers. Each twig was inoculated at six points with a hypodermic syringe. Gray spots appeared on the leaves of all trees in from six to seven days, and water-soaked spots appeared in great numbers about the tenth day. The inoculated tissue on the twig assumed a water-soaked appearance in from five to seven days and became dark brown in about twenty-five days. Poured plates from the spots on leaves and twigs yielded colonies of the organism more or less abundantly. All the twig check wounds soon healed, and the check leaves remained free from spots.

In 1911, at Ithaca, New York, cross inoculations with the four strains obtained from the twigs of the four different hosts were made on three-years-old Elberta peach and four-years-old Abundance plum trees. The organism from young-slant Hiss-glucose cultures was thoroughly mixed with sterile water and sprayed on the leaves with an atomizer. Twelve twigs were used in each case, and each twig was inoculated at five points with a hypodermic syringe. Spots on the leaves developed in nine days,

and after twelve days water-soaked spots appeared abundantly. The inoculated tissue on the twigs assumed a water-soaked appearance in most cases by the seventh day. The typical black-spot and black-tip condition of the twig did not develop until after the twenty-fifth day. Poured plate cultures from the young leaf spots and the black spots on the twigs yielded colonies of the organism abundantly. Pure cultures of the organism from the twigs of the four kinds of trees were grown side by side on various culture media for six weeks, and in all cultural characters the strains were the same. All check wounds on the twigs soon healed, and the check leaves remained free from spots.

In 1912, at Ithaca, cross inoculations with strains of the organism from twigs of the four hosts were made on three-years-old Alexander apricot, Early Violet nectarine, Elberta peach, and Burbank plum trees (Figs. 59, 65, and 66). One hundred leaves and from twelve to twenty twigs were used in each case. The organism from young-slant Hiss-glucose cultures was scraped into sterile water. The fingers were then dipped into the water, and the material was applied to the lower surface of the leaf by gently rubbing the leaf between thumb and fingers. Each twig was inoculated at from three to five points with a hypodermic syringe (Fig. 61). Spots on the leaves appeared in from five to seven days, and water-soaked spots became numerous after the eighth day. The inoculated tissue on the twigs took on a water-soaked appearance in about seven days, but did not become dark brown until after the twenty-fifth day. Both leaf and twig spots yielded the characteristic yellow colonies on poured plate cultures. All check wounds on the twigs soon healed, and the check leaves remained free from spots.

Morphology

Vegetative cells.— The organism is a rather short rod, with rounded ends. It is found singly, in pairs, and, in liquid media, often in short chains. Individuals from a forty-eight-hours-slant Hiss-glucose culture are from 0.8 to 0.9 μ in length and from 0.3 to 0.5 μ in width. Bacteria taken directly from the twig cankers and stained with gentian violet measure from 1.6 to 1.8 μ in length and from 0.4 to 0.6 μ in width.

Endospores.— No endospores have been observed.

Flagella.— The organism is motile by means of one or several polar flagella. Both Pitfield's and Moore's flagella stains were used with

good results. The flagella were also stained without a mordant, by exposing the covers to carbol fuchsin for from twenty-five to fifty minutes and carefully washing in alcohol (Fig. 67).

Capsules.— Capsules have frequently been stained in material obtained from Uschinsky's solution by both Welch's and Moore's methods.

Zoogloeæ.— Zoogloeæ are frequently found on various media.

Involution forms.— No involution forms have been observed.

Staining reactions.—The organism stains readily with the ordinary aqueous stains — aniline gentian violet, and carbol fuchsin.

Gram's stain.— Many efforts at staining were made with Gram's method, but the results were not sufficiently sharp and decisive to warrant a conclusion. In no case was the stain completely lost, nor was it ever retained in the original intensity. The aniline gentian violet and iodine solutions were used for two minutes and the preparations were left in absolute alcohol for three minutes. In no case were the mounts washed in alcohol as intensely stained as those not treated with alcohol, and consequently the organism must be regarded as Gram negative.

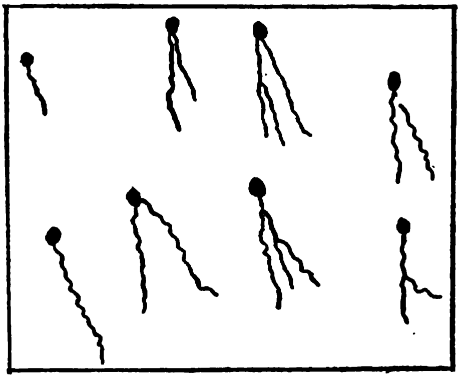

FIG. 67.—*Flagella of Bacterium Pruni. Stained from a culture of the peach strain of the organism grown in bouillon*

Acid-fast.— The organism is not acid-fast.

Cultural characters

Source of cultures.— Eighteen strains were used for each test, one from the apricot, one from the nectarine, nine from the peach, and seven from the plum. The reactions of all the strains on the various media were uniform, and no marked differences were observed except in one of the plum strains, which invariably grew most rapidly. The growth of this strain on potato plugs was more abundant than that of any of the other strains. Its growth on Hiss-glucose was often a number of hours in advance of the other cultures. Where there was any difference in the reaction one of the normal plum strains was always used as a basis for comparison.

Nutrient agar colonies.— When plantings were made from bouillon cultures six days old at room temperature of about 25° C., the colonies appeared as mere specks in from forty to forty-eight hours. Plantings made from diseased host tissue developed colonies in from three to ten days (usually from four to seven). No growth occurred at 37° C. The colonies were moist and glistening, and at first were almost white but later became amber yellow.[3] When not crowded, the surface colonies were round and reticulate, and reached a diameter of about one to five millimeters in ten days, with a smooth surface, an entire edge, and a finely granular internal structure. The deeper colonies were elliptical or lenticular. On plates twenty-five days old, colonies measured from ten to twenty-five millimeters in diameter. They had dark, translucent centers surrounded by a much lighter, often concentrically ringed, zone.

Nutrient agar streaks.— On slanted agar the streak made with a platinum needle developed a moderate amber-white (4) growth. The streak widened slowly, chiefly toward the bottom, made a filiform growth, and was raised, with a slightly contoured surface and an entire edge; it was translucent, with a glistening luster, and was slightly viscid; it did not color the agar on which it grew, at least not for a number of weeks. Growth was moderate. After five or six days the growth began to flow downward, and finally accumulated in an amber yellow (1), slimy mass at the base of the slant.

Nutrient agar stab.— On agar stab the growth was filiform, and was best toward the top of the stab, there being very little or no growth in the lower half of the medium. A circular colony formed on the surface at the point of inoculation, and gradually spread, completely covering the surface in about seven or eight days with a straw yellow (2) growth. The agar was not liquefied nor softened.

Gelatin colonies.— On gelatin plates at room temperature of about 25° C., the colonies appeared as mere specks in from forty-five to fifty hours. They were at first almost white, translucent, moist, and glistening. On the fourth day they measured about one millimeter in diameter. Both buried and surface colonies were round, finely granular, and with an entire edge, becoming with age amber yellow (2) in color. Liquefaction began usually on the third day, the colonies becoming saucer-shaped, spreading, and liquefying the medium in twelve days or more.

[3] All the color terms used in this paper are based on René Oberthür's *Répertoire de Couleurs*, published by La Société Française des Chrysanthémistes in 1905.

Gelatin streaks.— On slanted gelatin (+ 15) at room temperature of about 25° C., the streak having been made with a one-millimeter loop, a light, semi-transparent growth was noticed after two days along the entire path of the loop. In four days there was a slight liquefaction along the streak. On the fifth day the growth was amber yellow (1) in color, liquefaction had extended the entire length of the streak, and the growth was about ten millimeters wide and five deep. On the eighth day all material in the slant down to three millimeters below the base of the slant had been liquefied. Complete liquefaction occurred in from twelve to thirty days.

Gelatin stab. — In gelatin stab the path of the needle became beaded, but usually in the upper twenty-five millimeters of the medium it at first became more or less filiform. The growth on the surface was most rapid, and liquefaction, which began about the third day, soon passed to the walls of the tubes and then slowly downward. The growth in the depth of the gelatin soon ceased and the material along the track of the needle was not liquefied more rapidly than that away from its path. The liquefied gelatin was at first more or less clouded and was of about the same color as the solid material, but later it cleared and took on a raw sienna (2) color. A bacterial layer Naples yellow (3) in color soon formed on the solid gelatin and gradually settled as the material liquefied. Both a rim and a pellicle, cream yellow (2) in color, finally formed. Complete liquefaction occurred in from several days to six weeks or longer, depending on the temperature, the strain of the organism, and the composition of the culture material. In four months the liquefied material was viscid, was raw sienna (4) in color, and had a thick, slimy, Naples yellow (3), bacterial deposit in the bottom of the tube.

Hiss-glucose colonies.— Plantings made on Hiss-glucose from six-days-old bouillon cultures came up in from two to ten days (usually from four to seven) at room temperature of from 23° to 25° C., forming colonies from one to four millimeters in diameter in about eight days. No growth occurred at 37° C., but at 25° C. colonies appeared in forty-eight hours. The colonies were at first almost white, translucent, moist, and glistening, but later became amber yellow (1). When not crowded, the surface colonies were round, with an entire edge, the surface being smooth with a more or less convex elevation, and the internal structure being finely granular. The deeper colonies were elliptical or lenticular in form. Plates

containing twenty cubic centimeters of the medium developed single surface colonies in thirty days which measured from sixteen to thirty millimeters in diameter. The older colonies were amber yellow (4) in color, were convex, showed a dark central nucleus, and were often concentrically ringed. The smaller, thin colonies had a semi-transparent luster.

Hiss-glucose streaks.— On Hiss-glucose slant-tube medium (+15), the streak having been made with a millimeter loop, growth was noticed in forty-eight hours at room temperature of about 25° C. A convex, slimy, straw yellow (2) growth developed along the path of the loop. The streak widened gradually (chiefly toward the bottom), soon became filiform, and in ten days completely covered the slant with a slimy yellow (2) growth. In culture three or four months old the medium was browned. Some of the growth soon moved downward and formed a slimy deposit at the base of the slant, which finally became amber yellow (4) in color. As the medium dried out the slimy deposit gradually settled, and in the five- and six-months-old cultures there was a slimy, amber yellow (4) bacterial deposit from five to ten millimeters deep in the bottom of the tube. Inoculated tubes placed in the incubator at about 37° C. also covered the slants in ten days, but the growth was of about the same color as the medium.

Hiss-glucose stab.— In Hiss-glucose stab the growth was filiform and best toward the top of the stab, there being very little or no growth in the lower part of the tube. A circular growth formed on the surface at the point of inoculation, and covered the surface in six or seven days. The medium was not liquefied nor softened.

Potato agar streaks.— In potato agar a slightly raised, wet, shining growth developed along the path of the needle in two or three days at room temperature of 25° C. The streak gradually widened, and finally covered about two-thirds of the surface of the slant, becoming amber yellow (1) in color. Some of the slimy growth soon moved downward and formed a deposit at the base of the slant. Growth was moderate, never completely covering the slant.

Dextrose litmus agar streak.— In dextrose litmus agar, there was slight growth along the path of the needle in two days. The streak was slightly elevated, and widened most rapidly at the bottom, becoming filiform. The slimy growth passed downward and accumulated at the base of the

slant, and the medium below the mass became entirely bleached in five or six weeks.

Lactose litmus agar streak.— Growth in lactose litmus was not so marked as on the dextrose litmus medium. There was slight growth along the path of the needle by the close of the second day. The streak was slightly elevated, and it gradually widened and became filiform. The slimy growth passed downward and accumulated at the base of the slant. Growth was less abundant, and bleaching below the slimy mass only slight, at the end of six weeks.

Potato plugs.— Potato plugs were placed in running water for three hours, and were then put into tubes containing over five cubic centimeters of distilled water (the lower end of the plugs being in the water) and sterilized for twenty-five minutes at 100° C. for three consecutive days. The streak was made with a platinum needle from a six-days-old nutrient agar culture. The tubes were kept at room temperature of about 25° C. A slightly yellow, glistening streak developed along the path of the needle in two days. It made a moderate, slightly raised, echinulate growth, covering from one-half to two-thirds of the slant in about ten days but never completely covering it. One of the strains, however, repeatedly covered the entire surface of the cylinders in from five to six days. The growth had a contoured, wet, glistening, amber yellow (2) appearance. It was slimy, was free from odor, and turned the cylinder slightly gray. Most of the strains had only a slight action on potato starch.

Bouillon.— Both meat broth and meat extract bouillon were used. The meat broth material gave an acid reaction of + 15 Fuller's scale, and the meat extract bouillon recorded + 12. Inoculations were made from a three-days-old bouillon culture. All cultures were kept at about 25° C.

The medium was clouded after from twenty-four to forty-eight hours. An amber yellow (1) rim formed in from twelve to fifteen days, followed by formation of a pellicle. On being shaken, the material settled in the form of yellow, viscid flakes. The material cleared in about six or eight weeks and became raw sienna (3) in color, with a slimy, amber yellow (2) bacterial growth in the bottom of the tube. Very little difference was observed in the growths of the organism in extract bouillon and in broth bouillon.

Milk.— The milk used was maize yellow (1) in color, due to overheating in sterilizing, and was about 1.8 per cent acid. All tubes were

inoculated with a one-millimeter loop of beef broth culture three days old, and kept at 25° C. Two days after inoculation there was a slight whey ring at the surface of the milk; after four days the ring was three or four millimeters deep. Smith (1903) states that this organism slowly precipitates casein, which is then gradually redissolved.

In about ten days the whey ring was five or six millimeters deep and was amber yellow (3) in color, and the fluid curd gradually changed to yellowish tan (4) in color. The amount of clear whey gradually increased, and in about twenty-five days it became gamboge yellow (2) and the curd gradually became sienna (4) in color. The whey was viscid, while the mobile precipitate finally became a compact, slimy mass. An amber yellow pellicle was formed in from fifteen to twenty days. Filamentary threads often extended from the pellicle to the curd below. The pellicle finally settled. On shaking tubes containing a well-formed pellicle, yellow, slimy threads sometimes extended from the surface of the medium to the bottom of the tube.

An amber yellow (2) layer of the organism soon formed on the curd, and gradually lowered in the tube as the curd dissolved. About the twenty-second day many white tyrosine crystals formed in this layer.

About the forty-fifth day the pellicle in many cases had settled. The whey now constituted three-fourths of the material, was viscid, and was saffron yellow (4) in color. The precipitate was a yellow-buff (1), slimy mass dotted with white tyrosine crystals.

In four-months-old cultures the material was about one-half dried out and the whey constituted about one-half of the material. It was Indian chestnut-red (2) in color, with a thick, slimy, fawn-colored (2) coagulum dotted with white tyrosine crystals.

Litmus milk.— In the test with litmus milk, the culture material had been incubated at 37° C. for forty-eight hours just before the inoculations were made. It was violet (4) in color, and a one-millimeter loop of a three-days-old beef broth culture was used for inoculating each tube.

On the second day a bluish violet (4) ring two millimeters deep had formed on the surface of the medium, and by the fourth day the surface ring was from six to eight millimeters deep, in many cases having an amber yellow (1) rim. The material below the bluish violet (4) ring still retained its original color, but gradually became dark violet.

In about fifteen days the top ring became pansy violet (4) in color and was from eight to ten millimeters wide. The amber yellow (4) rim was more prominent and usually a pellicle was formed. In some cases the deposit below the whey had changed to madder brown (2) in color.

By the twenty-fifth day an amber yellow (1) pellicle had formed, in some cases with filamentary threads extending to the deposit below. On shaking of the tubes, the pellicle formed into thick, slimy threads sometimes extending from the surface of the medium to the bottom of the tube. In some cases the litmus was wholly reduced by the twenty-fifth day. The whey ring was about twenty-five millimeters deep, with the upper five millimeters pansy violet (3) and the lower twenty millimeters yellow lake (3) in color. The deposit in the bottom of the tube was brownish drab (2) in color, and was covered with an amber yellow (1) layer of the organism often three to four millimeters deep. Many white tyrosine crystals had formed in this layer. In about forty-five days the pellicle had settled, leaving a dull yellow-green (1) rim. The litmus had been in some cases completely, and in others only partially, reduced, but the material in most of the tubes had returned to a darker color. The whey by transmitted light was plum-violet (4) in color. There was a thick, slimy, brown-drab (2) deposit in the bottom of the tube, about 10 millimeters deep, and on the top of this an amber yellow (2) layer of the organism. Tyrosine crystals were scattered throughout the entire slimy mass.

In four-months-old cultures one-half of the material had dried out. The pellicle had settled, and a plum-violet (3) whey ring about twenty millimeters deep covered a thick, slimy, brownish drab (2) deposit six millimeters deep in the bottom of the tube. An amber yellow (2) layer of the organism on the top of the deposit was still rather prominent. Masses of white tyrosine crystals appeared throughout the entire slimy deposit.

Fermentation tubes.— A basal solution was made by adding two per cent of Witte's peptone to water. Six solutions were made from this, each containing one per cent, respectively, of one of the following carbon compounds: glycerin, saccharose, mannite, dextrose, maltose, lactose. Five fermentation tubes were filled with each of these solutions and sterilized by heating for twenty-five minutes on three successive days. Three tubes of each set were inoculated and two were left as a control. The inoculated tubes each received a one-millimeter loop of culture material from a five-days-old peach bouillon culture.

Five days after inoculation a cloudiness appeared in the open arm of each of the inoculated tubes. This turbidity increased with age, extending more than halfway into the U in the dextrose, saccharose, and maltose cultures; but at the end of twenty-five days there was no growth in the closed arm and no gas. There was a well-defined line between the growth in the bulb and the clear liquid in the closed arm, which seemed to point strongly toward the aërobic nature of the organism. A pellicle had formed on all the dextrose, maltose, and saccharose cultures, and in most cases there was a yellow, slimy growth of the organism at the bottom of the open arm. There was very little growth in the mannite tubes.

The cultures were tested for acidity after they had grown for twenty-five days. In glycerin the acidity increased from + 0.8 to + 1; in saccharose, from + 0.9 to + 1.1; in mannite, from + 0.9 to + 1; in dextrose, from + 1 to + 2.5; in maltose, from + 0.8 to + 1; in lactose, from + 0.8 to + 1.1.

Uschinsky's solution.— In the test with Uschinsky's solution, tubes were inoculated from a four-days-old broth culture. A one-millimeter loop of the material was placed in each tube.

The tubes were all clouded after three days. The solution often became viscid in about twenty-five days. A cream yellow (1) pellicle formed in from twenty to thirty days or later. The pellicle finally settled, forming a slimy, cream yellow (3) bacterial mass in the bottom of the tube.

Sodium chloride bouillon.— A one-millimeter loop of a six-days-old, + 12, peptonized beef broth culture was placed in tubes of peptonized beef broth containing, respectively, 1, 2, 3, 4, 5, 6, and 7 per cent of chemically pure sodium chloride. Three tubes were inoculated with cultures of each kind of host — apricot, nectarine, peach, and plum. At the end of seven days clouding was apparent in all tubes containing 1, 2, and 3 per cent of sodium chloride. Both the peach and the plum organisms grew in a 3.5-per-cent salt bouillon. There was no clouding in the 4-, 5-, 6-, or 7-per-cent solutions.

Growth in bouillon over chloroform.— By means of a sterile pipette, five cubic centimeters of chloroform was added to fifteen cubic centimeters of bouillon. Fifteen tubes were shaken twice a day during the period of this test. On the eighth day the tubes were divided into five lots, four of which were inoculated with six-days-old bouillon cultures of apricot, nectarine, peach, and plum organisms, respectively; the fifth lot being used as a

control. These cultures were under observation for thirty-two days, but no growth was observed in any of the tubes.

Nitrogen nutrition.— In filtered river water containing one per cent of asparagin, the organism made a slow initial growth first visible in six days. When distilled water was used the first signs of growth failed to appear before the tenth day, and in some cases as late as the fifteenth day, even when the strongest, oldest cultures were used. A very slight growth was obtained in river water containing only dextrose. River water alone failed to give any growth.

Nitrates.— Twelve tubes, each containing ten cubic centimeters of peptonized beef broth to which had been added one per cent of nitrate of potash, were divided into four lots of three tubes each. The solutions in each lot were then inoculated with apricot, nectarine, peach, and plum strains, respectively.

At the end of ten days the tubes were clouded and a tube from each lot was tested for nitrates in the following manner: To each culture one cubic centimeter of boiled starch water and one cubic centimeter of potassium iodide solution (1–200) were added. A few drops of sulfuric acid were then introduced. The peach and plum cultures gave a slight blue reaction, and on the twentieth day the remaining tubes each gave a distinct reaction. However, six months later these experiments were again repeated three times, with the same strains of the four organisms, and not a single culture gave the reaction.

Indol.— A number of tubes of Uschinsky's solution with the addition of one per cent of Witte's peptone were inoculated with a five-days-old agar culture. Apricot, nectarine, peach, and plum strains were used in making these inoculations. The inoculated tubes all showed considerable growth on the fifth day, but a test for indol was not made until the tenth day. Sulfuric acid water (1–2) and dilute sodium nitrate (1–200 in water) were used. On the tenth day all cultures gave a slight rose color after being placed in boiling water for two minutes, indicating indol production. The other tubes were tested twenty days later and a well-marked indol reaction was obtained from all the cultures.

Cultures of the four strains made in Dunham's peptone solution gave positive results at the end of twenty days. There was a trace of pink before heating, and after four or five minutes in a water bath at 80° C. the reaction became distinct.

Toleration of sodium hydroxide.— Beef bouillon having a reaction of +10 Fuller's scale was used. Sufficient sodium hydroxide was added to obtain a reaction of 0, —2, —4, and so on for every two degrees of Fuller's scale to —30. The sodium hydroxide was added just before the last sterilization. Titrations made immediately following the sterilization, while the medium was still warm, showed an apparent loss of alkalinity. In many cases, although not always, the check lots of the medium titrated on the fifth day or later gave the original reaction.

Tubes inoculated and placed in an incubator at 25° C. gave a good growth in all cultures down to —10 in forty-eight hours. There was a slight growth in the —10 cultures, and at the end of two weeks a very slight growth occurred in the —13 cultures. No growth occurred in the tubes containing larger amounts of sodium. The best growth was in cultures containing from —2 to —4 sodium hydroxide.

Toleration of hydrochloric acid.— Ordinary beef bouillon having a reaction of + 12 Fuller's scale was used. Sufficient hydrochloric acid was added to 100 cubic centimeters of the bouillon to obtain a reaction of + 14, + 16, and so on for every two degrees of Fuller's scale to + 36. There was a very good growth in forty-eight hours in all the tubes up to + 22, and a slight growth in the lot having a reaction of + 24. A very slight growth was observed on the fourth day in the medium having a reaction of + 26; this growth became slightly stronger by the tenth day. No growth occurred in any medium containing larger quantities of acid. The best growth developed in lots containing from + 12 to + 20 acid.

Resistance to drying.— Small drops of four-days-old bouillon culture were placed on sterile cover glasses in a covered sterile petri dish, and left in an incubator at room temperature of from 18° to 23° C. At intervals of twenty-four hours one of the cover glasses was transferred to a tube of sterile bouillon. Three tubes were used for each test. Growth occurred up to the eighth day, after which the tubes remained sterile.

This experiment was repeated a number of times with bouillon cultures from four to ten days old. As a rule there was no growth after the eighth day; in one case, however, growth occurred on the fifteenth, and in another case on the twenty-first, day.

Effect of sunlight.— Hiss-glucose tubes inoculated from a three-days-old bouillon culture were poured into petri dishes and placed in the bright sunlight for forty-five and sixty minutes, respectively, half of each plate

being covered with black paper. After six days, on each of six plates there were numerous colonies on the covered parts but none on the exposed parts. A few colonies, however, developed on the uncovered parts of all the plates exposed for fifteen, twenty, and thirty minutes.

Effect of germicides.— Poured Hiss-glucose plates were made with the plum organism after it had been exposed to various concentrations of copper sulfate, mercuric chloride, formaldehyde, lime-sulfur solution, the self-boiled lime-sulfur mixtures, and arsenate of lead.

In a copper sulfate solution (1–10,000), colonies appeared in five days on all plates on which cultures were made of the organism which had been exposed for one-half minute and for five minutes. However, there were only one-fourth as many colonies on the five-minutes exposures as on the one-half-minute exposures. No colonies appeared on any of the plates on which the organism had been exposed for fifteen minutes and for thirty minutes.

In a mercuric chloride solution (1–150,000), colonies appeared in five days on all plates on which cultures were made of the organism which had been exposed for one-half minute and for five minutes. The colonies on the plates exposed for five minutes remained small and failed to develop the yellow color. No colonies appeared on any of the plates on which the organism had been exposed for fifteen minutes and for thirty minutes.

In a formaldehyde solution (1–300), colonies appeared in five days on all plates on which cultures were made of the organism which had been exposed for one-half minute and for five minutes. However, there were three times as many colonies in the one-half-minute exposures as in the five-minutes exposures. No colonies appeared on any of the plates on which the organism had been exposed for fifteen minutes and for thirty minutes.

In a lime-sulfur solution (15–15–50 formula) in a 1–10,000 dilution, colonies appeared in five days on all plates on which cultures were made of the organism which had been exposed for one-half minute and for five minutes. However, there were only one-half as many colonies on the five-minutes exposures as on the one-half-minute exposures. No colonies appeared on any of the plates on which the organism had been exposed for fifteen minutes and for thirty minutes.

In a self-boiled lime-sulfur mixture (8–8–50 formula) in a 1–52 dilution, colonies appeared in five days on all plates on which cultures were made

of the organism which had been exposed for one-half minute and for five minutes. No colonies appeared on any of the plates on which the organism had been exposed for fifteen minutes and for thirty minutes.

In arsenate of lead, 1–208 dilution, colonies appeared on all plates on which the organism had been exposed for one-half, five, fifteen, and thirty minutes, respectively.

Diastatic action.— The test for diastatic action was made on potato cylinders. Twenty-eight strains of the organism were grown on potato cylinders for twenty-five days. The cultures were then tested for starch reduction, and only one of the strains showed marked diastatic action. In all the other cases the only indications observed were a slow and slight tendency toward the conversion of starch into amylodextrin, shown by a gradual change in the iodine reaction from a clear blue to a purplish tint.

These tests were made according to the directions given by Harding and Morse (1909): "These potato cultures were crushed in porcelain mortars and 50 cubic centimeters of water added to separate the particles so that the effect of the iodine could be easily seen. The presence of unchanged starch was determined by the gradual addition of a weak solution of iodine in potassium iodide. After a sufficient amount has been added to satisfy some of the other compounds which are present the starch grains are turned to a blue-black. The extent of the reduction of the starch by the bacterial growth is estimated on the basis of similar tests of uninoculated potato cylinders."

The uninoculated cylinders, when tested with the iodine-potassium-iodide solution diluted with water, always yielded a bright blue reaction. The starch reaction was also strong after the organism had been grown on the cylinders for several weeks, although a purplish color indicated a slight diastatic action.

Fragments of potato scraped from under the yellow slime from a culture forty days old, mixed with about twenty times their bulk of water, gave a purple or a blue-purple reaction. When fragments of material from the back or the center of the cylinder were used and treated in the same way, they invariably gave the blue reaction. The water below the potato cylinder, when it contained more or less of the yellow slime of the organism, also invariably gave a purplish blue reaction.

Pepsin.— A peptonizing ferment must be present, since gelatin is liquefied and casein is slowly dissolved with the formation of tyrosine.

Lab ferment.— In the milk cultures the casein is thrown out of solution without marked acid production, which indicates the presence of a lab, or rennet, ferment.

Invertase.— Cultures of all four strains of the organism were grown in filtered river water containing two per cent of chemically pure saccharose and two per cent of Witte's peptone. On the twenty-fifth day all the cultures were tested for inverted sugar with Fehling's solution, and every culture gave the glucose reaction.

Thermal death point.— Preliminary tests indicated that the thermal death point must lie between 49° and 54° C. The following tests were made to determine the point more nearly: Six sets of twelve tubes each of peptonized beef broth were inoculated with the peach organism from a five-days-old-slant Hiss-glucose culture, and the tubes were placed in water at a constant temperature of 49°, 50°, 51°, 52°, 53°, and 54° C., respectively. The tubes were removed at the end of ten minutes, and were kept at 25° C. for two weeks. At the end of five days growth had taken place in all the tubes that had been exposed at 49° and 50° C. Growth appeared also in three of the twelve tubes that had been kept at 51° C. No growth appeared at the end of fourteen days in tubes that had been kept for ten minutes at 52°, 53°, and 54° C.

The experiment at 51° and 52° C. was repeated several times with different strains of the organism, and in a few instances growth occurred in cultures kept at 51° C. for ten minutes. There was never any growth in cultures kept at 52° C.

The thermal death point, therefore, is about 51° C. Smith (1903) also placed the thermal death point of this organism at about 51° C.

Optimum temperature.— The optimum temperature appears to lie between 24° and 28° C. Growth at 24° and at 28° C. on Hiss-glucose and peptonized beef bouillon was considerably better than at 32° C. Growth at 20° and at 36° C. was about the same, but was considerably less than at 32° C. and much less than at 24° or 28° C.

Maximum temperature.— Four-days-old bouillon cultures of ten strains of the organism were used to inoculate slant Hiss-glucose medium. Six tubes were used for each strain; three tubes of each lot were placed in an incubator at 37° C., and three were kept at room temperature. All cultures, both in the incubator and at room temperature, made good growth; however, those exposed to the higher temperature were of the

color of the medium, while those in the lower temperature had developed the normal yellow color. On the fifteenth day the heat of the incubator was reduced to 25° C.; on the sixteenth day one of the cultures had taken on a yellow color, and by the eighteenth day all the cultures had developed the normal color. From these results it is evident that 37° C. is close to the limit of growth for the organism on Hiss-glucose.

In a series of experiments, slant Hiss-glucose and bouillon cultures were kept at 20°, 24°, 28°, 32°, 36°, and 40° C., respectively, for three weeks. Six-days-old bouillon cultures of four strains of the organism were used for making the inoculations. Two three-millimeter loops of the fluid were used for each tube. Three tubes of bouillon and two of the slant Hiss-glucose medium were used in each set. Five tubes of bouillon and three of the Hiss-glucose medium were also inoculated and were placed at room temperature (from 23° to 25° C.), to serve as checks. All strains of the organism on both kinds of media made decidedly the best growth at 24° and at 28° C. They also made better growth in both media at 20° than at 32° C., and the growth at 32° was considerably better than at 36° C. There was no growth at 40° C.

The growth on Hiss-glucose cultures kept at 20° and at 24° C. developed the normal yellow color; tubes kept at 28° C. developed a growth a shade lighter in color; those kept at 32° C. were much lighter, and had a mere trace of yellow; in those kept at 36° C. the yellow shade had disappeared entirely, and the growth was of the color of the medium.

Loss of virulence.— Park (1905) states that " bacteria differ . . . as to the ease and rapidity with which they grow in any nutritive substance and the amount of poison they produce. Both of these properties not only vary greatly in different members of the same species, but each variety of bacteria may to a large extent be increased or diminished in virulence."

In June, 1910, four cultures, one each from apricot, nectarine, peach, and plum twigs, were obtained at Mountain Grove, Missouri. All the cultures were grown continuously on a Hiss-glucose medium. It was observed that the plum organism obtained at this time was the most vigorously growing strain in the laboratory. In the inoculation work in Missouri during 1910 it was also the most aggressive on all four hosts. In the work at Cornell University during 1911 the writer was much surprised to find that not only had this strain lost its vigor on the various

culture media, but the injury was also far less marked when it was inoculated on the green tissues of the different hosts. In the fall of 1911 Abundance plum twigs were inoculated with cultures of this strain, and in the summer of 1912 the organism was regained from one of the twigs. The culture was again grown continuously on a Hiss-glucose medium. The regained culture made a slightly better growth on the various media than did the culture which had been growing continuously on the Hiss-glucose medium, and was also slightly more aggressive when inoculated on the green tissues; but it was far less virulent than when first obtained. In the summer of 1912 the four old strains which had been growing continuously on the Hiss-glucose medium since 1910 were rejuvenated by growing them in bouillon for fifteen days, making transfers to a new medium every third day, and finally on the fifteenth day all were again placed on the Hiss-glucose medium. The plum organism at once became again the most vigorous grower, and when inoculated on peach leaves and twigs it was also the most aggressive. From these results it appears that vigor is the controlling factor in the virulence of the organism.

Group number.— The group number, according to the descriptive chart of the Society of American Bacteriologists, is 211.2232523.

Life history

Inoculation.— *Bacterium Pruni*, so far as is known, passes its entire life cycle in nature within the tissue of the host. The disease usually makes its appearance in the spring shortly after the leaves have unfolded, but as a rule serious outbreaks do not occur before May and often not until later. Cankers on the twigs and limbs are the principal sources of infection in the spring. Trees bearing twigs on which inoculations result in the development of well-formed cankers, are invariably the first to develop leaf spot abundantly the following year. Young trees which suffer severely from repeated outbreaks of the shot-hole condition usually show many twig cankers. Twig cankers are also constantly associated with the early spring outbreaks on older trees. The tissues of the bud may likewise become invaded, and are often responsible for the early spring infection. Eleven out of fifty cultures made from the centers of buds taken in August from peach twigs on which the foliage was badly shot-holed, yielded many colonies of the yellow organism.

The bud cut from bud wood obtained from an infected tree often conveys the organism to healthy stock. Laboratory experiments indicate that when exposed to sun and air the bacteria which lodge on twigs and buds retain their vitality for only a very short time.

If the twigs are killed after the cankers are well formed, the organism may remain alive in the dead tissue for a considerable time. Many peach and plum twigs cross-inoculated by the writer in the summer of 1910 died in the following winter, but cultures of the organism were repeatedly obtained from the dead twigs up to the middle of the next June. From that time on it was impossible to secure cultures from this source. Cultures were readily obtained, however, from the cankers on the green inoculated twigs.

Old leaves on the ground, if well protected from sun and air, may possibly harbor the organism for some time, but it is doubtful whether they ever constitute an important source of infection. It is possible that pruned twigs and limbs left on the ground may occasionally be the source of primary infection, but in the large percentage of cases the primary infection can be traced to cankers on twigs and limbs of the trees. The writer's experiments indicate that the organism soon loses its vitality in material on the ground.

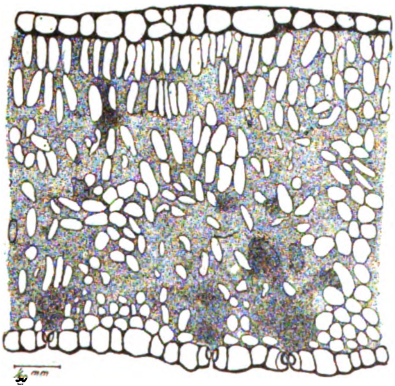

FIG. 68.—*Cross section of a peach leaf which was inoculated with a strain of Bacterium Pruni from the fruit of the plum. The material was collected eight days after the inoculation had been made. The organism entered the leaf through the stomata. (Drawing made with the aid of a camera lucida)*

In October, 1911, fifteen hundred peach leaves, one thousand plum leaves, and fifty peach twigs, which had been cross-inoculated with cultures of the four strains of the organisms, were put between wire screens and left over winter on the ground, where they were fully exposed to the sun. In April, 1912, all attempts to regain the organism from these twigs and leaves failed. In another experiment, however, Hiss-glucose poured-plate cultures made on June 1, 1913, from diseased leaves that had been collected on October 10, 1912, and kept in the laboratory between blotters, yielded colonies of the organism.

The organism gains entrance to the host through the stomata (Figs. 68 and 69) and the young lenticels during periods of sufficient moisture. A film of water on the surface of the leaf, the twig, or the fruit enables the bacteria to move about and gain entrance to the substomatal cavity. Inoculation ordinarily does not take place in the absence of moisture. Lenticels and stomata are fairly well distributed on the young twigs, and the stomata are more or less plentiful on the green fruit and on the lower surface of the leaves, but there are none on the upper leaf surface. Consequently inoculation may occur anywhere on the young, tender twigs and the green fruit, while on the leaves the organism can gain entrance only from the lower side.

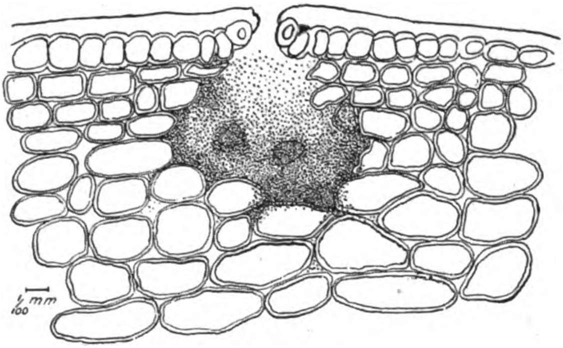

FIG. 69.—*Early stage of fruit spot on Burbank plum fruit. The fruit had been inoculated with a strain of Bacterium Pruni, isolated from a peach tree. The material was collected seven days after the inoculation was made. It was fixed in strong alcohol, infiltrated with paraffin, and cut on the microtome. The sections were stained with acid fuchsin.* (*Drawing outlined with the aid of a camera lucida*)

In 1911, at Ithaca, New York, 332 Elberta peach leaves of different ages were inoculated in the early morning. A few drops of water containing numerous bacteria in suspension were placed, by means of a pipette dropper, on the upper or the lower surface of each leaf. In all, 149 of the leaves were inoculated on the upper, and 183 on the lower, surface. In four weeks 177 of the leaves inoculated on the lower surface contained many spots; 6 were clean. All the 149 leaves inoculated on the upper surface were free from infection. In the same year 100 plum leaves were inoculated in the same way, 40 on the upper and 60 on the lower surface. At the end of five weeks, 55 of the leaves inoculated on the lower surface contained many brown spots, and 5 were free from lesions. All the leaves inoculated on the upper surface were free from spots. All the check leaves were normal.

From the results it was evident that a moist lower surface is essential for inoculation and spread of the pathogen on the leaves. Observations show that dew plays quite as important a part in the dissemination of the pathogen as does rain. Rain and dew are not only important factors for inoculation, but they also carry the bacteria to the healthy leaves, twigs, and fruit, and thus frequently serve as agents of transportation.

The bacteria are no doubt carried from tree to tree and disseminated on the young leaves, fruit, and growing twigs by insects of various kinds. Waite (1898), Stewart (1913), and others have proved that bees, wasps, flies, snails, aphids, and beetles carry the pear blight organism from oozing cankers to open blossoms and young shoots, and thus spread the blossom and twig blight of apples and pears throughout the orchard. From the large numbers of various insects often found working on the diseased foliage and fruit of trees affected with *Bacterium Pruni*, and from the nature of the bacterial ooze, there appears little doubt as to the importance of insects in the dissemination of this organism.

In spring, when the weather is cold and unfavorable for the development of the organism and the insects are sluggish, only a few primary inoculations occur and only a few scattered spots develop on the foliage. As the season advances and the weather becomes warmer, the bacteria multiply and escape from the spots of the early infections, the secondary infections gradually become abundant, and the leaves that contained only a few spots at first soon become dotted with them. Insects also become more active, and secondary spots of infection multiply rapidly.

In the inoculation experiments on plum leaves in 1913, snails and aphids were undoubtedly the chief agents in conveying the organism from the inoculated diseased leaves to the young leaves as they unfolded. The new leaves of the trees on which there were no snails nor aphids remained free from infection. Poured plate cultures were made from each of eleven snails and eighteen aphids collected from these trees. Three of the snail cultures and two of the aphid cultures yielded colonies of the organism.

The great frequency with which infection occurs on the leaves along the path taken by ants leaves little doubt that these insects also aid more or less in spreading the disease. Nevertheless, cultures from more than one hundred ants gave negative results.

As a rule, insects merely carry the virus from leaf to leaf or from tree to tree, and seldom introduce the bacteria directly into the tissue of the host.

Still the writer has frequently obtained cultures of the organism from both feeding and egg punctures of curculio on fruit, and in a number of cases it has been practically certain that the insect was the agent of inoculation.

Infected leaves are often blown about by the wind, and no doubt are sometimes responsible for the occurrence of primary infection. Yet danger from this source is comparatively slight, since the leaves soon dry out and the bacteria quickly lose their vitality. The disease usually advances in the orchard in all directions from a center of infection, often forming a more or less circular diseased area. After the organism has become established, the movement of limbs and branches caused by high wind during storms also furnishes a means of conveyance for the bacteria from diseased to healthy organs.

Old neglected trees, the plum in particular, often serve as sources of inoculum. In the past seven years two outbreaks of the disease on the Missouri State Fruit Experiment Station grounds were traced directly to infected Burbank, Abundance, and Golden plum trees.

Where the organism has become well established, diseased trees may serve as a source of inoculum and young trees planted in adjoining fields gradually become diseased. In 1906 a very striking case of this sort came under observation. A tract of one hundred and sixty acres of land on the east side of an old peach orchard at Koshkonong, Missouri, which contained many infected trees, was planted in the spring with two-years-old Elberta peach trees. In October the foliage and twigs of the trees in the ten rows next to the old trees were badly diseased. During 1907 the organism gradually advanced, and by the close of the season the trees in one hundred and ten rows were infected. The disease, however, was much worse in the first thirty rows than in the others. During 1908 the organism spread entirely across the orchard and every tree in the entire tract was injured to a greater or less extent. The trees in the first thirty rows next to the old orchard suffered most severely, and many of them were permanently injured.

Man himself is often an important agent of inoculation. In selecting material for budding, nurserymen frequently cut twigs from diseased trees, and thus, by inserting the infected bud material, inoculate the stock.

In 1907, on the Missouri State Fruit Experiment Station grounds, several thousand healthy peach seedlings were budded with buds taken

from infected Elberta twigs. During 1908 the shot-hole condition developed on the foliage of nearly all these trees, and cankers were more or less plentiful on the twigs of many of them. Trees of this sort, when set out, not only grow poorly, but also serve as centers from which all neighboring trees become inoculated. In the course of the past five years several cases have come under observation in which a few infected trees from a poorly kept nursery were mixed in large shipments of clean trees. The infected trees served after planting as inoculum centers, and three years after planting every tree in these orchards was diseased.

In a careful inspection of peach and plum trees in various sections of South Carolina, not a single case of the disease was observed on isolated seedling peach and plum trees; yet the organism was repeatedly collected on the budded peach and Japanese varieties of plum in both family and commercial orchards, indicating that the nurseries are largely responsible for the spread of the pathogen.

Incubation.—The period of incubation varies more or less, depending on temperature, moisture, and method of inoculation. The period is about the same on all four kinds of trees. In some cases, however, it appears to be slightly longer on leaves and twigs of apricot and plum than on those of the nectarine and the peach.

In experiments in which the organism was suspended in water and applied to the leaves and fruit with an atomizer in warm, moist weather, the period apparently varied from seven to fifteen days, but in cold weather the period was prolonged to twenty and even twenty-five days. When water containing the organism was applied in warm weather to the lower surface of the leaf and to the fruit by means of a pipette dropper, and was spread by gently rubbing leaf or fruit between the thumb and the fingers, signs of disease appeared on the leaves in from five to seven days and on the fruit after seven or eight days; in cold weather, however, the period was considerably extended on both leaves and fruit. On the twigs, considerable difficulty having been experienced in obtaining results with the spray and rubbing method, a hypodermic syringe was used. The needle was inserted just beneath the cuticle and a small quantity of water containing the bacteria was forced into the tissue. Very uniform results were obtained in this way. The period of incubation following these inoculations varied from four to ten days, depending largely on the temperature and on the number of organisms forced into the tissue. In the

twig experiments moisture did not influence the period of incubation to so marked an extent as in the experiments with leaves and fruit.

Infection.—Infection occurs soon after the bacteria pass through the stomata into the substomatal chambers, where they multiply and secrete a cytolytic enzyme which soon breaks down the cell walls of the neighboring cells, giving the organism access to an abundant food supply.

Serial sections made from infected plum fruit show that the organism at first occupies merely the substomatal chamber, but the neighboring cells are soon broken down, and as the bacteria multiply, the deeper tissues become involved. In about six or seven days a small cavity filled with bacteria is formed, and the first evidence of disease appears in the form of a water-soaked spot just beneath the stomata. A cross section through one of these spots shows the cavity filled with a compact mass of bacteria (Fig. 69, page 411). In about ten days or more, depending much on the weather conditions, the bacteria escape to the surface through the stomata or a slight central rupture. In some cases the bacteria burrow deeper and spread laterally, forming a somewhat circular, sunken, black area. The bacteria reach the surface through the various stoma and central rifts.

The tissues of the leaf are invaded in much the same way as are those of the fruit. At first the parenchyma tissues are those principally involved, but finally the vascular bundles also may be attacked (Fig. 68, page 410). The external signs of injury sometimes appear a day or two earlier on the leaves than on the fruit, and the ooze may also be evident a little earlier. The area in which the cells have been broken down assumes a more or less circular form and soon becomes separated by a line of cleavage from the healthy tissue. The injured tissue within this area soon contracts, dries out, and falls away, leaving a fairly clean-cut hole in the green tissue.

The tender tissues of the young shoots are also injured in much the same way, but the incubation period in the older tissues of the twigs is apparently longer and the development of the water-soaked spots is often slower. A cross section through one of these spots also shows a cavity filled with a compact mass of bacteria. The black-spot condition on the twig appears in from twenty to thirty-five days. Many of the phloëm cells of the sunken black area are broken down and the entire tissue is more or less

disorganized (Fig. 70). Radial rifts or pockets in the young wood and cortex extend outward, often to the epidermis. As the twigs increase in

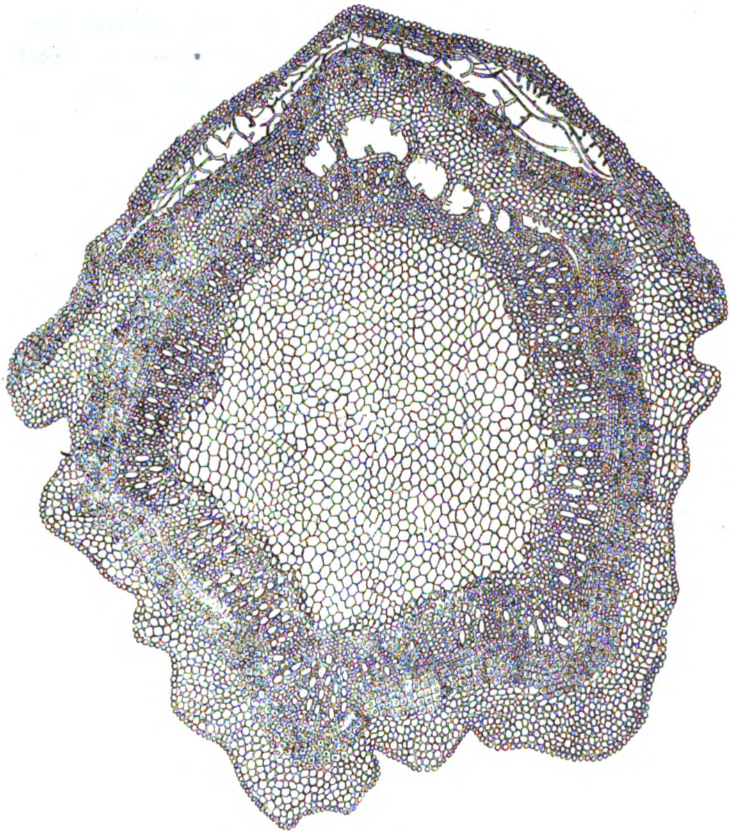

FIG. 70. — *Cross section of a young peach twig inoculated with a pure culture of Bacterium Pruni obtained from a plum twig. Bacterial pockets are most abundant in the cortical parenchyma. All cortical parenchyma cells in the infected region are distorted. The bacterial pockets in the cambium region also are to be noted. Occasionally the large ducts in the young wood are filled with the organism*

size these rifts open and form an approximately longitudinal fissure. The bacteria escape through these fissures in countless numbers as bacterial ooze.

New infections occur only on the current season's growth. The organism is most aggressive in the young, tender tissues of the twigs. As the tissues harden, the influence of the organism in many cases becomes less marked and the blackened areas gradually become lighter in color; by the close of the season these areas have in many cases assumed much the same color as the old bark. During the second year a large proportion of the twig cankers thus disappear. A cross section of a twig through such cankers shows that no new bacterial pockets have appeared near the cambium zone and the old cavities have gradually been crowded into the outer bark. The organism, however, in some cases at least, is still alive and active, and no doubt often serves as a source of inoculum.

EFFECT OF ENVIRONMENTAL FACTORS

The condition of the weather is the most important environmental factor with respect to this disease. This is particularly true as regards moisture, but temperature is also of marked consequence. The shot-hole condition does not usually appear until about the middle of May or the first of June. In a very warm, damp spring, however, it may appear as early as the first of April, while in other years severe outbreaks may not appear until in August or even later. A temperature of from 20° to 28° C. is the best for the growth of the bacterium. Cold weather not only retards its growth, but also checks the activities of insects, which are the important agents in disseminating the organism. In the writer's spring and fall field work, it was frequently observed that when a cold period followed immediately after a series of inoculations had been made, the growth of the organism was retarded, and in some cases three, and even four, weeks passed before signs of disease appeared. The warm, slow, continued rains of the summer furnish the best conditions for the rapid spread of the disease. Heavy, driving rains of short duration followed by sunshine and winds are not favorable to its spread, since many of the bacteria are washed to the ground, and the leaves are quickly dried off and the few bacteria that may be spread will be quickly dried and killed.

The foliage of eight three-years-old peach trees, which were growing in boxes in the open, was inoculated with pure cultures of the organism. In three months the foliage on all the trees was dotted with brown spots. Four of the trees were then moved into the greenhouse and water was applied only to the roots. No new spots appeared on the old leaves

after the second week, and all the new leaves that developed in the greenhouse remained free from infection, while the leaves of the four trees in the open continued to develop many new spots.

The relation of moisture to the spread of the disease is also brought out to a marked extent in the field when a favorable wet period is followed by a dry period. All the leaves formed in wet weather contain many brown spots and usually develop the shot-hole condition more or less, while those formed in a dry period remain free from spots, the contrasts in the foliage of the two periods being sometimes very striking.

Heavy dews, if the temperature does not fall too low, also furnish favorable conditions for inoculations, and observations indicate that they often play quite as important a part in the progress of the disease as does rain.

Shaded situations are favorable for the growth of the organism. Direct sunlight soon kills it. However, since the stomata of the leaves occur only on the lower surface, and the twigs and the fruit are usually fairly well shaded by the leaves, only comparatively few of the organisms ever become exposed to the direct rays of the sun.

In dry seasons injury from this organism is very slight, especially if the spring has been cold. Infections in such seasons are found only in the center of the tree, where the foliage remains moist from the dew until late in the day.

While it is true that temperature and moisture are the factors that govern the distribution of the organism, yet soil conditions, fertilizers, and cultivation have a marked influence on the extent of injury done. The soil in which the trees are growing has a considerable influence on the development of the disease. When a general outbreak occurs in an orchard, the trees on the higher, thin ridges invariably suffer more than those on the lower, more fertile land. Trees that have borne the heaviest crops in previous years invariably suffer more than do those that have yielded little or no fruit in previous seasons. Young trees planted in new land properly broken up before planting are more nearly free from the disease than trees planted on land poorly prepared. Trees properly pruned and well cultivated show less disease than do those that are not pruned nor cultivated.

VARIETAL SUSCEPTIBILITY

Observations show that the different varieties of the various hosts exhibit considerable variation in their susceptibility to the disease. The

plums show the greatest variation. The majority of the American varieties suffer little, if at all, while nearly all the Japanese varieties, especially Abundance and Burbank, are severely injured, in some cases the disease resulting in the formation of deep limb and trunk cankers and in eventual death of the tree. Similar wounds are occasionally formed also on some varieties of apricot, nectarine, and peach, but they are far more abundant on Japanese varieties of plum.

The fruits of different varieties of the four kinds of hosts also show considerable variation in susceptibility. The nectarines suffer the greatest injury, the fruits of all the varieties of this host in Missouri being so badly cracked that they are usually destroyed by the various rot-producing organisms while still green. The effects of the disease on the fruits of Japanese plums, especially Abundance and Burbank, are nearly as severe as on the nectarines. The greater proportion of the fruits are badly distorted and cracked and the small number that are not rotted before they ripen are so badly injured that they are worthless for market. As a rule, apricot fruits are injured to a less extent than those of the nectarine or plum, but the variety Royal is severely affected. Though the fruits of some varieties of peaches, particularly Elberta, are severely injured, they are as a rule less badly disfigured than are the fruits of the nectarine or the Japanese varieties of plum (Fig. 63c).

In addition to this variation in susceptibility of the different varieties, there is also considerable variation in the amount of injury to the fruits of a given variety during different seasons. The real significance of these latter variations is not always easy to explain, but in most cases the age of the fruit and the weather conditions determine largely the percentage of infection.

In table 1 is given a list of the apricot, nectarine, peach, and plum trees in the variety orchard of the Missouri State Fruit Experiment Station, showing the nature and degree of susceptibility of the different varieties. These figures represent the average record for the year 1909. An estimate of the percentage of infection on leaves, twigs, and fruit was made by passing through the orchard, estimating and recording the injury. After the estimates had been made several trees in different parts of the orchard were carefully examined and the actual percentage of infection was obtained by counting the diseased leaves, twigs, and fruits. The difference found between the actual and the estimated percentages of infection

formed the basis for correction of all the varietal estimates. Three estimates were made in the course of the summer, the first in the middle of July, the second August 5 to 7, and the third September 26 to 29. The average result of the three records is given here as the record for the year.

TABLE 1. RELATIVE SUSCEPTIBILITY OF DIFFERENT VARIETIES OF APRICOT, NECTARINE, PEACH, AND PLUM TO BACTERIUM PRUNI*

Apricot

Bread, 40-30-30-f
Moorpark, 40-20-0-f
Peach, 75-30-0-a
Russian, 30-10-?-a
Superb, 20-15-0-p
Sweet Russian, 40-20-30-p

Nectarine

Coosa, 45-15-100-a
Munson's Cling, 50-8-85-a
New White, 58-8-100-p
Stanwick, 65-15-100-a
Victoria, 60-10-100-a

Peach

Alexander, 25-15-5-p
Alice Hampton, 20-15-35-p
Alton, 40-20-80-a
Amsden June, 8-5-25-f
Arkansas Beauty, 35-15-50-a
Arkansas Mammoth, 50-10-50-f
Arkansas Traveler, 40-10-0-a
Arnett, 55-10-?-p
Arnett No. 6, 65-5-?-a
Athens, 40-3-30-a
Banner, 15-8-35-n
Barber, 8-5-0-f
Barnard Early, 35-10-60-a
Barnes, 5-3-0-f
Beauty, 30-10-50-a
Belle (Belle of Georgia), 15-3-25-a
Bell's October, 20-10-25-n
Bequette Cling, 23-3-45-p
Bequette Free, 40-10-70-a
Bernice, 35-10-25-f
Bilyeu, 60-10-100-a
Bishop, 18-18-0-f
Blanchard, 55-10-45-a
Blood Cling, 45-10-0-p
Blood Free, 50-10-30-p
Blood Leaf, 55-5-45-a
Bokhara, 0-10-40-n
Bonanza, 45-15-60-p
Brandywine, 6-13-40-f
Bray's Rareripe, 25-15-30-f
Brett (Mrs. Brett), 20-30-30-a
Brigdon, 40-10-20-a
Briggs (Briggs' May), 18-18-40-f
Bronson, 30-15-25-a
Burke, 20-10-35-p
Carman, 60-0-30-p
Carpenter (Carpenter Cling), 35-5-50-a
Chairs (Chairs' Choice), 30-20-35-a
Champion, 60-0-30-p
Champion Yellow, 15-5-30-f
Charlotte (Early Charlotte), 35-10-?-p
Cherokee, 25-20-45-a
Chili (Hills' Chili), 20-10-30-p
Chilow, 25-40-25-p
Chinese Cling, 45-15-30-a
Chinese Free, 45-5-55-a
Christiana, 30-5-25-a
Cloves, 43-3-50-p
Cobler, 25-15-20-p
Coleman, 20-10-30-p
Collridge Favorite, 30-10-30-a
Columbia, 35-15-40-a

*The first number following the name of the variety indicates the percentage of infected leaves; the second, the percentage of defoliation; the third, the percentage of infected fruit ("?" in the third place indicates that the tree bore no fruit). The letter in the fourth place indicates the number of twig cankers observed: a, abundant; p, plentiful; f, few; n, none. The letter in the fifth place (in the plum varieties) indicates the amount of injury due to trunk and limb cankers: e, extreme injury causing the death of the trees; m, marked injury; s, slight injury; n, no injury.

Peach (*continued*)

Conkling, 13-8-0-f
Connecticut, 43-3-60-p
Connet (Connet's Early), 15-10-60-f
Cora, 80-8-10-a
Crosby, 13-3-0-f
Crothers, 60-0-100-a
Davenshire, 40-20-0-a
Davidson, 35-20-50-p
Dawson's Early, 25-2-0-f
Delaware, 45-5-60-f
Deming (Deming's September), 60-10-40-a
Denton, 55-15-45-a
Dewey (Admiral Dewey), 20-10-0-p
Diamond, 50-20-30-a
Dover, 45-5-70-a
Early Barnard, 10-20-0-n
Early Crawford, 10-5-25-f
Early Heath, 35-5-25-p
Early Michigan, 30-5-80-a
Early Rivers, 30-15-40-f
Early York, 40-10-50-a
Ede (Captain Ede), 15-10-25-p
Edgemont Beauty, 11-5-25-p
Elberta, 80-30-45-a
Elberta Cling, 60-10-53-a
Eldred, 65-15-35-a
Emma, 50-15-50-a
Engle (Engle's Mammoth), 15-10-0-f
Etna, 20-10-25-p
Eureka, 45-10-55-a
Family Favorite, 80-10-70-p
Fischer, 65-5-100-p
Fitzgerald, 35-10-35-a
Flatters St. John, 65-5-80-a
Flemer's Cling, 65-5-98-a
Flewellen, 35-5-33-a
Floyd, 50-10-40-a
Ford's No. 1, 50-0-70-p
Ford's White, 40-10-25-f
Foster, 30-20-30-p
Fox (Fox Seedling), 18-8-35-a
Frances, 30-10-50-a
Froth's Early, 65-15-55-a
Future Great, 20-10-25-p
Garfield, 13-8-35-p
Geary's Hold-on, 28-8-25-p
General Taylor, 5-5-95-p
Gilman's Favorite, 50-10-45-a
Globe, 15-10-50-p
Gold Drop, 21-10-60-p
Gold Dust, 30-75-30-p
Golden Gate, 50-20-?-a
Gold Medal, 40-10-30-a
Gold Mine, 30-10-35-p
Gordon, 20-15-30-f
Grand Reporter, 55-15-50-a
Hale Early, 38-8-40-p
Heand's Beauty, 60-10-45-a
Heath (Heath Cling), 60-20-60-a
Heath Free, 60-20-25-a
Henrietta, 8-5-40-f
Hiley, 26-1-40-p
Hill's Madeira, 25-5-40-p
Hobb's Late, 15-10-22-f
Hobson, 30-25-?-a
Holderbaum, 20-5-25-f
Honi Chirf, 35-10-30-p
Hoover's Heath, 20-10-10-n
Horton's River, 45-15-70-p
Hughes I. X. L., 30-10-0-p
Hyde's Yellow, 20-5-20-f
Hynes (Hynes' Surprise), 20-10-30-f
Indian Blood Cling, 10-10-0-n
Indian Blood Free, 50-10-40-a
Ingold (Lady Ingold), 30-20-90-a
Japan Blood, 55-5-0-a
Jaques (Jacques' Rareripe), 15-15-25-f
Jennie Worthern, 35-10-30-a
Juno, 45-5-30-a
Kalamazoo, 10-8-0-f
Kerr (Jessie Kerr), 25-10-0-f
Krummel's October, 20-10-45-p
Late Crawford, 40-10-40-a
Late Elberta, 60-15-35-a
Laure Cling, 35-5-30-a
Lemon Cling, 12-10-0-f
Lewis, 0-10-50-n
Lodge, 40-10-60-a
Lola (Miss Lola), 25-10-40-f
Lorentz, 33-8-0-p
Louise (Early Louise), 35-15-0-a
Lovell No. 3, 50-0-?-a
McCallister, 20-15-?-f
McIntosh, 13-8-0-p
Madison County Mammoth, 40-10-70-a
Magnum Bonum, 35-30-25-a
Mamie Ross, 20-10-40-a
Mammoth Cling, 75-15-50-a
Marshall, 30-10-30-p
Mathews (Mathews' Beauty), 50-20-50-a
Mena, 40-10-?-a
Michigan, 10-5-0-n
Mid September, 23-8-25-p
Mint's Free, 30-20-80-p
Mixon Late, 75-5-30-a
Moore's Favorite, 20-15-50-a
Morris Late White, 50-10-30-p
Mountain Rose, 25-15-70-p

Peach (*concluded*)

Muir, 25–15–30–a
Munson's Cling, 65–15–100–a
Munson's Free, 60–10–70–a
Nanticoke, 23–8–30–f
Nelson's No. 5, 40–10–45–a
New Prolific, 10–15–25–f
Niagara, 45–5–40–p
Nicholson's Smock, 40–10–40–p
October Free, 50–10–33–a
Olden No. 1, 40–10–25–p
Olden No. 3, 50–10–100–a
Oldmixon Cling, 55–15–30–a
Oldmixon Free, 50–20–35–a
Oldmixon Improved, 30–15–45–p
Orange Cling, 40–20–35–p
Oriole, 30–3–55–p
Oritz, 28–18–40–a
Oscar, 63–8–70–a
Ozark Queen, 20-20–40–p
Pallas, 43–3–70–a
Pearce's Yellow, 30–10–0–p
Peento, 5–5–?–n
Pendleton, 40–10–25–a
Perry's Red Cling, 35–15–?–p
Plaut, 50–10–35–a
Pond's Seedling, 70–10–40–a
Pool's Favorite, 8–3-0–f
Queen, 40–20–50–p
Rasin Cling, 35–25–60–p
Ray, 20–5–30–p
Red Heath, 35–5–25–a
Red River, 60–15–30–a
Reeves Yellow, 20–15–0–f
Reynolds, 18–8–25–f
Ringgold, 40-10–40–p
Rivers, 58–8–25–a
Robert, 50–20–30–a
Rodgers, 20–5–45–p
Rose of Baltimore, 48–8–30–a
Rush's Favorite, 30–10–65–a
Russell, 23–20–20–n
St. John, 50–20–80–a
Salway, 15–15–35–f
Schofield, 60–0–40–a
Scott's Nonpareil, 65–15–40–a
Sea Eagle, 30–10–30–f
Sea Eagle Improved, 25–10–30–f
Shipler, 42-15–60–a
Shoemaker, 20–2–0–n
Smock (Smock's Free), 50–20–50–a
Sneed, 70–25–40–a
Snow, 35–10–25–a
Snow Free, 30–5–45–p
Snow's Orange, 23–10–0–n
Springfield, 50–10–40–p
Steadley, 30–10–35–p
Stevens, 60–10–35–a
Stevens Late, 20–20–40–f
Stinson, 65–15–65–a
Strout's Early, 15–10–?–f
Stump, 15–10–40–p
Success, 30–10–20–p
Summer Snow Cling, 40–10–55–a
Superb, 40–20–40–p
Sussex's Late, 35–5–45–p
Sylphide, 33–13–23–p
Texas (Texas King), 10–5–65–f
Thurber, 15–3–30–f
Tillotson (Early Tillotson), 10–12–0–n
Toledo (Early Toledo), 35–5–0–p
Topaz, 15–15–50–a
Tornado, 30–10–60–p
Trebout, 50–20–70–a
Van Buren, 30–3–?–p
Waddell, 60–10–45–a
Wager, 30–15–25–n
Walker (Walker's Variegated Free), 20–15–30–p
Ward's Late, 65–15–40–a
Washington Cling, 60–10–50–a
Waterloo, 20–0–40–p
Webb's Golden, 50–5–70–f
Wheatland, 40–10–?–a
Wheeler's Late, 75–5–25–a
Wilkins' Cling, 38–8–45–a
Willett, 50–15–30–a
Williams' Favorite, 40–10–23–p
Wilson's No. 14, 45–5–?–p
Wonderful, 35–15–0–n
Worth, 55–15–40–a
Wright, 5–3–30–n
Yellow Rareripe, 25–15–0–f

Plum

Abundance, 100–60–100–a–e
America, 40–20–20–p–s
American Eagle, 55–15–10–a–e
Apple, 90–40–?–a–m
Arkansas (Arkansas Lombard), 0–0–0–n–n
Assiniboia, 55–20–?–p–n
Best of All, 45–15–0–a–n
Broadshow, 0–0–?–n–n
Burbank, 100–60–100–a–e
Case Gold Drop, 0–0–?–n–n

Plum (*concluded*)

Chabot, 85–15–100–a–m
Clifford, 0–0–10–n–n
Cumberland, 20–0–0–a–m
Downing (Charles Downing), 55–20–0–n–m
Diamond, 0–0–?–n–n
Douglass, 80–20–0–a–m
Damson (Blue Damson), 0–0–?–n–n
Elapa, 55–20–0–n–n
Funk, 0–0–?–n–m
Gonzales, 95–30–?–a–m
Grand Duke, 0–0–?–n–n
Guthrie Topaz (Topaz), 63–25–?–n–n
Hale, 90–35–?–a–m
Hattankio (Hytankio), 50–15–10–a–m
Hawkeye, 50–15–0–p–n
Hungarian Prune, 0–0–?–p–n
Italian Prune, 0–0–0–n–n
Jefferson, 0–0–?–n–n
Jones Special, 75–25–30–n–n
Kerr, 60–25–?–a–m
Krap, 55–33–0–p–n
Kroh (Poole's Pride), 40–20–10–f–m
Lacy, 100–45–?–n–n
Lombard, 0–0–?–n–n
Maryland, 0–0–0–n–n
Milton, 0–0–0–n–n
Monarch, 50–20–?–p–n
Newman, 40–20–10–f–n
October (October Purple), 85–40–?–a–m
Ogon, 95–30–30–a–e
Orleans (Smith's Orleans), 0–0–?–n–n
Owanka, 55–15–?–n–n
Peter's Gage, 0–0–?–n–n
Pond (Hungarian Prune), 0–0–?–p–n
Pride (Shipper's Pride), 30–12–?–f–n
Purple Leaf, 90–35–?–a–m
Quaker, 45–15–50–p–m
Reagan, 55–25–0–n–n
Red Goose, 40–20–?–n–m
Red June, 95–25–100–a–e
Red Nagate, 100–50–?–a–m
Red October, 55–10–0–a–m
Reine Claude, 40–8–?–p–n
Robinson, 40–15–100–n–m
St. Martin (Coe's Late Red), 0–0–?–n–n
Shropshire (Shropshire Damson), 0–0–?–n–n
Sophie, 40–10–10–f–n
Stella, 95–55–?–p–n
Tokeya, 40–10–?–n–n
Wakapa, 55–15–?–n–n
Ward October, 40–10–20–p–m
Ward October Red, 45–15–0–a–m
Wastesa, 75–35–?–p–n
Whitaker, 0–0–0–n–m
Whiting, 0–0–?–n–m
Wildgoose, 40–10–0–n–m
Willard, 100–40–?–p–e
Winnipeg, 55–25–?–f–s
Wohanka, 50–25–?–n–n
Yellow Egg, 0–0–?–n–n
Yosemite, 90–30–10–a–e
Zekanta, 48–15–?–n–n

CONTROL

Observations and experiments in control were made principally with peaches and plums, as only a few varieties of apricots and nectarines were available for experimental work. This phase of the subject may be discussed under four heads: exclusion, eradication, protection, and immunization.

EXCLUSION

In budding, the greatest care should be exercised in selecting material only from trees known to be free from the organism. Even though the twigs are free from cankers, the organism may be transferred to the healthy stock through infected buds. Laboratory and field experiments made at the Missouri State Fruit Experiment Station show that it is impossible to determine from the external appearance of the bud whether it is infected.

In preparing to set out an orchard, great care should be used in ordering the trees. Purchases should be made only from reliable nurserymen, and, if possible, the nursery should be visited and the trees inspected in the fall, while they are still in full leaf, in order to make sure that the foliage is free from shot-hole condition and the twigs are free from cankers. If this is impossible, the trees should be carefully examined for black cankers in the spring, before they are set out. The disease is usually more easily detected in fall than in spring. All infected trees should be rejected.

Since the organism is readily carried from one tree to another, the location of a young orchard or nursery in relation to old, diseased trees or orchards is of considerable importance. The writer has frequently observed old orchards which served as centers of inoculum for young trees. In 1906 a tract of one hundred and sixty acres of new land near Koshkonong, Missouri, which bordered an old peach orchard on the south, was set with two-years-old Elberta peach trees. During the first year the foliage on the trees in the first fifteen rows became more or less diseased, but during the second year the disease advanced more rapidly and the foliage on trees in the two hundred and fifty rows next to the old orchard became involved. The trees beyond this, however, were normal and were making satisfactory growth. At the end of the third year nearly every tree in the entire orchard was diseased. Those in the first fifty rows bordering the old orchard contained more twig cankers than did those in any other part.

ERADICATION

After the disease has once become established, the chief point of attack is, of course, the cankers on twigs, limbs, and trunks of the trees, since these wounds not only serve to carry the organism through the winter but also in many cases tide it over unfavorable periods in summer. Careful pruning not only removes many of the twig cankers — and very often the cankers near the tips of the twigs contain the greatest numbers of bacteria — but also serves to stimulate new growth which often shows considerable resistance to the attacks of the organism. It is of course impossible to remove all the twig cankers in a crop season. But in an off year, when the fruit buds have all been winterkilled, the twig cankers on the old trees can be removed by cutting back the limbs to one-fourth of their entire length and carefully trimming out all the

one- and two-years-old twigs from the center of the trees. Lesions on the limbs and trunks soon form rough, open cankers and can easily be found. Such wounds must also be cut out, or, if this is impossible, the diseased tissue must be completely removed by cutting around the canker well into the healthy part of the limb or the trunk. In every case the wound should be thoroughly disinfected with corrosive sublimate solution, one part to one thousand parts of water. The organism can usually be eliminated in this way on the apricot, the nectarine, and the peach. In the case of the plum, however, especially on the Japanese varieties where the organism has invaded the large limbs and the trunk, it is practically impossible to save the tree.

In 1907 the peach trees in the Missouri State Fruit Experiment Station variety orchard were heavily pruned. All the limbs were cut back one-fourth of their length. One hundred and thirty Elberta trees of the same age were not severely pruned but were treated in every other way as the other trees. During the fall the foliage on the pruned trees was of a better color and more nearly free from disease than that on the unpruned trees. In 1908 little or no injury was observed on the pruned trees, while foliage on all unpruned Elberta trees was more or less diseased. Twenty per cent of the leaves finally fell, and twig cankers also were plentiful. Chandler,[4] of the University of Missouri, has also observed in his work that severe pruning tends to make the trees more nearly free from the shot-hole disease.

PROTECTION

Spraying

Since bordeaux mixture has been used successfully in controlling various plant diseases, and lime-sulfur has been used also with more or less success, a number of experiments were undertaken in order to determine the effectiveness of these mixtures in controlling this organism.

In 1908, thirty-two eight-years-old Elberta peach trees were sprayed seven times with bordeaux mixture, and twelve were used as checks. The first application was made with the 6-4-50 formula on March 12, just before the fruit buds opened. The other six applications were made with the 2-9-50 formula after the leaves had unfolded; the first of these was made on April 21, and the others followed at intervals of from twelve to fifteen

[4] Chandler, W. H., in a letter dated September 26, 1912.

days. On August 12, the leaves, the twigs, and the fruit on the sprayed trees were free from disease. The fruit was of excellent color and quality, but there was sixty-one per cent less fruit on these trees than on the checks. The leaves on the checks were badly shot-holed and about ten per cent of them had fallen. The twigs also contained many blackened cankers. Sixty-three per cent of the fruit was infected.

In the same year, twenty-nine eight-years-old Elberta peach trees were sprayed seven times with lime-sulfur. Eleven trees were used as checks. The first application was made with the standard 15-15-50 formula on March 12, just before the buds opened. The other six applications were made with self-boiled lime-sulfur, 12-8-50 formula, after the leaves had opened; the first of these was made on April 21, and the others followed at intervals of from twelve to fifteen days. On August 12 the foliage on the sprayed trees was more or less dotted with diseased spots. The twigs also showed a few black cankers. Fifty-two per cent of the fruit contained many small bacterial wounds, but otherwise it was in good condition (Fig. 64). The yield was reduced twenty per cent. On the check trees the foliage was badly injured and ten per cent of the leaves had fallen. The twigs also showed many cankers. Sixty-three per cent of the fruit was diseased and cracked, its market value being considerably reduced.

In 1909, twenty-two nine-years-old Elberta peach trees were sprayed four times with peach bordeaux mixture, 2-9-50 formula. Twelve trees were used as checks. In 1908 curculio punctures made it difficult to determine the exact extent of injury due to the attack of this organism, and therefore in all the spraying experiments in 1909 arsenate of lead was added to the mixture used in the first two applications. The poison was added at the rate of two pounds to fifty gallons of the spray mixture. The first application was made about seven days after the petals had fallen, and the three others followed at intervals of four weeks. On August 8, as far as could be observed, the leaves, the twigs, and the fruit were free from disease. The foliage on the check trees was badly injured, and fifteen per cent of the leaves had fallen. The twigs contained many black cankers. Sixty-five per cent of the fruit was injured, and most of this was worthless.

In 1909, twenty-four nine-years-old Elberta peach trees were sprayed four times with self-boiled lime-sulfur, 12–8–50 formula. Arsenate of lead was added to the first two applications at the rate of two pounds of the

poison to fifty gallons of the mixture. The first application was made about seven days after the petals had fallen, and the three others followed at intervals of four weeks. On August 8 only a few spots were observed on the leaves, and the twigs were apparently free from cankers, but fifteen per cent of the fruit was infected. The foliage on the check trees was badly injured, and fifteen per cent of the leaves had fallen. Many of the twigs were badly cankered. Sixty-three per cent of the fruit was infected, and most of this was worthless.

Apparently the arsenate of lead improved the effectiveness of the self-boiled lime-sulfur solution. It is quite probable, however, that the beneficial results obtained from the addition of arsenate of lead are due rather to the control of insects which serve as agents of dissemination than to the improvement of the mixture as a fungicide. Laboratory tests show that arsenate of lead used at the rate of two and one-half pounds to fifty gallons of water has very little influence on the growth of this organism.

From these and other experiments, it is evident that bordeaux mixture will control the disease. But the foliage of the trees, especially in the case of peach and nectarine, is extremely sensitive to the action of copper, and in some cases the trees are defoliated even when the copper is used at the rate of one-half pound of copper sulfate to nine pounds of lime and fifty gallons of water. Self-boiled lime-sulfur alone is much less effective, and in all the writer's experiments it failed to control the disease; but when two pounds of arsenate of lead were added to fifty gallons of the mixture it became much more effective.

Cultivation

A tract of about two hundred acres of new land at Koshkonong, Missouri, was set in 1906 with two-years-old Elberta peach trees which were more or less infected with the organism. Strips about four feet wide were plowed across the field and trees were set on the plowed land. The orchard was fairly well cultivated during the first three years. The organism gradually spread from the diseased to the healthy trees, and at the end of the third year every tree in the entire tract was more or less infected. Many of the trees were stunted and some of them finally died. Their death, however, could not be attributed directly to the work of this organism, but was apparently due to a combination of winter injury of the roots, premature defoliation due to the work of the bacteria, and, finally, the

invasion of the roots by one of the root rot organisms. The trees of this orchard were uneven and produced very little fruit.

In the same year another tract of about one hundred acres of new land was planted with two-years-old Elberta trees brought from the same nursery. In this case the ground had been thoroughly prepared and the orchard was carefully cultivated during the following three years. A number of infected trees were observed in different parts of this orchard in the first year, but the disease spread very little and by the end of the third year all traces of disease had disappeared. The trees developed uniformly and produced large crops of excellent, clean fruit.

Diseased trees that have been properly cultivated invariably hold their leaves longer and resist the influence of the organism much better than do poorly cultivated trees. The general vigor of the host plays an important part in controlling the disease. Trees standing in thin, poor soil invariably suffer more severely than do those standing in more fertile places. Trees that yield abundantly are less resistant than those that produce little or no fruit. The foliage of infected trees that yield full crops in two consecutive years usually falls prematurely if the trees are not liberally fertilized and well cultivated.

In the spring of 1907 the peach trees in the Missouri State Fruit Experiment Station variety orchard were cut back severely, and about the middle of May complete fertilizer at the rate of 800 pounds to the acre was applied to the soil on one-half of the orchard. The same amount was applied also to an acre of Elberta peach trees of the same age which had not been cut back. Both the variety orchard and the Elberta orchard were finally planted in cowpeas. On September 1 the foliage on the trees that had been cut back and fertilized was in good condition and no premature defoliation was observed. The foliage on the Elberta trees, which had been fertilized and not cut back, was in fair condition, but from two to five per cent of the leaves had fallen. The foliage of the trees that had been cut back and not fertilized was more or less injured and from ten to twenty per cent of the leaves had fallen. The most striking results, however, appeared in September, 1908. The trees in the fertilized and cut-back block were practically free from disease. The foliage on the Elberta trees, which had been fertilized and not cut back, was more or less diseased, twenty per cent of the leaves had fallen, and many of the twigs contained black cankers. The foliage on the block of trees which

had been cut back and not fertilized was much improved, not over two or three per cent of the leaves had fallen, and the twigs on very few of the trees contained cankers.

Chandler,[5] in a series of commercial fertilizer experiments conducted at Brandsville, Missouri, from 1910 to 1912, also has shown that the organism can be controlled to a large extent by the use of fertilizer. He obtained excellent results in using from 700 to 800 pounds of complete fertilizer per acre on mature trees and from 300 to 400 pounds on trees from two to three years old. Applications were made once a year in early spring or in June. Those made in June apparently gave better results than those made in spring. Chandler's results show that nitrate of soda is the essential element for controlling the disease. All plots that received nitrate of soda, whether alone or in combination with either potassium chloride or acid phosphate or both, showed very great resistance to the disease, but the plots receiving only potassium or phosphorus or both did not show any increased resistance. In the plots treated with nitrate of soda a few leaves were affected, yet very few fell as the result of the disease and the foliage had a healthy color. In some cases the trees of the check plot and those treated with potassium chloride and acid phosphate lost as high as fifty per cent of their leaves.

An application of manure well worked into the soil gives excellent results and in some cases the improved condition of the trees is more permanent than when commercial fertilizer alone is used. Good results have been obtained by seeding down the orchard permanently to red clover after a liberal application of manure. The clover is cut from time to time and allowed to rot under the trees. This practice, however, has disadvantages and cannot be recommended for general use. Very good results have been obtained also by following an application of manure with cowpeas. The tops are not cut but are allowed to stand until killed by frost, and the following spring the dead material is carefully worked into the soil. After the first year commercial fertilizers and cowpeas are used, but if the trees show marked improvement nitrate of soda is omitted from the fertilizer, since the cowpeas as a rule furnish sufficient nitrogen. This method gives good results. The peas, however, furnish an abundant food supply for mice, which are likely to injure the trees during the winter.

[5] Chandler, W. H., in a letter to the writer dated September 26, 1912, containing a summary of some of his commercial fertilizer experiments with peach trees. A detailed account of the experiments will finally be published by the Missouri Experiment Station, Columbia, Missouri.

IMMUNIZATION

No doubt much can be accomplished in the way of resistance by crossing the less resistant with the more resistant varieties. This is especially true in the case of plums.

RECOMMENDATIONS FOR CONTROL

Since the organism is spread largely in the nursery, great care should be exercised in selecting trees for planting. Stock should be bought only from reliable nurserymen, who should be required to guarantee the trees to be free from the disease. A single diseased tree may cause serious loss after the trees are set out.

Old, neglected, budded apricot, nectarine, peach, and plum trees, especially plum, usually harbor the organism and become a menace to young orchard trees. All such trees should be cut down before the young trees are set out.

The ground must be thoroughly plowed before the young trees are set, and about one pound of a complete fertilizer should be worked into the soil about the tree while it is being set. Too much care cannot be given to the cultivation of an orchard, especially during the first two or three years.

Where the organism has become thoroughly established, systematic pruning, cutting out, and careful removing of all the diseased tissue from the cankers on the limbs and the trunks of the trees will eliminate the source of infection to a large extent. Complete eradication on old trees (seven or eight years old), however, can be accomplished only by pruning the trees. Pruning not only tends to eliminate the source of infection, but also serves to stimulate new growth which is more resistant to the disease.

Where the trees have been heavily pruned, a thorough application of bordeaux mixture (4 pounds of copper sulfate, 4 pounds of lump lime, and 50 gallons of water) just before the buds open will be of considerable assistance in controlling the disease on the fruit, especially if this application is followed by two or three applications of arsenate of lead (2½ pounds of arsenate of lead, 4 pounds of lump lime, and 50 gallons of water) to control the curculio and other insects, which aid materially in disseminating the organism. The first application of arsenate of lead should be made just as the shucks slip; the second, two weeks later; and the third, about two weeks after the second.

The older trees that are in good condition are as a rule not seriously injured by the disease. Thorough cultivation of an orchard and the use of fertilizers are absolutely essential. Complete fertilizer, at the rate of about 600 pounds to the acre in early spring for mature trees and from 150 to 300 pounds for young trees, gives very good results. In crop seasons a second application of about 250 to 300 pounds of the fertilizer should be made in June; the amount of nitrate of soda in this application should be reduced by about one-half. A liberal application of stable manure in the spring, well worked into the soil, will also give excellent results. Close attention to pruning and to the chemical and physical conditions of the soil will practically control this disease.

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AGRICULTURAL EXPERIMENT STATION OF

THE COLLEGE OF AGRICULTURE

Departments of Entomology and Plant Pathology

THE CONTROL OF INSECT PESTS AND PLANT DISEASES

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THE CONTROL OF INSECT PESTS AND PLANT DISEASES

Few growers of crops realize the annual loss caused by insects and fungous diseases. It is safe to say that in the State of New York the loss from these sources alone exceeds the amount annually appropriated by the Legislature for conducting the State's business. From careful spraying experiments conducted by the growers themselves under the direction of Professor F. C. Stewart, of the New York State Experiment Station at Geneva, it is shown that the average annual preventable loss to potato growers in this State from blights and insects is nearly fifty bushels to the acre. This represents a loss of over ten million dollars yearly, which might be saved by an expenditure of less than five dollars an acre for spraying. A careful estimate of losses from the loose smut of oats in this State shows that ten per cent of the crop is destroyed annually by this fungous disease, a net loss of over a million dollars in 1914. The losses from apple scab and codling moth, from San José scale, peach yellows, and fire blight, and from all the other common insect pests and destructive plant diseases, if they could be accurately estimated, would show a grand total of appalling magnitude. This tremendous annual tax on the plant production of the State might be greatly reduced by the proper application of *known* methods of control.

The method of control to be employed for a given insect pest or fungous disease must be determined by the nature and habits of the enemy and by the character of the crop attacked. Plants can seldom be cured of disease as are men and animals. They must be protected from the attack. If sucking insects are to be controlled, something must be applied that will kill when it hits them, as whale-oil soap or nicotine solution; if biting insects are to be combated, the fruit and foliage must be sprayed or dusted with a poison that when eaten will destroy the pest. Many fungous diseases are prevented by spraying the plants, before the disease appears, with a mixture poisonous to the fungus but harmless to the plant. The poisons that destroy fungi are seldom effective against insects, and hence we have fungicides and insecticides. Often these can be combined in one mixture for insect and fungous pests of certain crops, as, for example, arsenate of lead and lime-sulfur for controlling codling moth and apple scab.

It is not to be supposed that spraying is the only means of controlling diseases. Many fungi are perpetuated from year to year in or on the seeds of the crop, as, for example, the smut of oats and wheat, or the pod spot of beans. In such cases it becomes necessary to treat the seed in order to kill the fungus, or to select seed free from the disease. Special

methods of cultivation, soil treatment, sanitation, and the like, are means of controlling these pests and maladies, to be practiced, as is spraying, only in those cases in which they have been shown to be especially applicable.

In order to successfully apply these measures for control of a given disease, certain factors must be taken into consideration. For example, in spraying apple trees for scab, the stage of development of the buds, the blossoms, and the fruit, together with the character of the weather rather than the day of the month, must be the guide in making the application.

For nearly all fungous diseases the spray should be applied before rains, not after. Fungous spores are scattered and germinate during rains, seldom after. The plants should be protected by having the mixture on when the rain comes. *Bordeaux or lime-sulfur does not wash off easily. When spraying for insect pests alone, the mixture should be applied after rains. The spraying should be done thoroughly.* Every leaf and fruit must be coated in order to be protected. *A nozzle that gives a fine, misty spray should be used.* This requires also good pressure behind the nozzle. The amount of pressure required to do good work varies with the type of nozzle. It should never be less than 75 pounds, and some types of nozzles require 175 pounds in order to do the best work.

Timeliness and *thoroughness* are more important factors in the control of diseases and insect pests than are the particular mixtures of poisons used.

For purposes of control, insects are divided into two great classes:

(1) *Chewing insects*, or those having jaws by means of which they bite off and eat portions of the tissues of the plant. Examples are Colorado potato beetle, cankerworm, and codling-moth caterpillar. (2) *Sucking insects*, or those with a beak containing four bristles united into a slender tube. The bristles are inserted into the plant, and through them the insects suck out the sap. Examples are squash stinkbug, San José scale, and plant louse (Fig. 191).

FIG. 191.—*A plant louse, one of the sucking insects, showing the beak*

Chewing insects are usually controlled by applying to their food poisons such as paris green, arsenate of lead, or hellebore. *Sucking insects* cannot be reached in this way and must be killed by a direct application of contact insecticides, such as soaps, oils, or other substances. In fighting sucking insects thorough and skillful work is required, since every individual insect must be hit by

the spray; while in the case of chewing insects, it is merely necessary to apply the poison thoroughly to the food-plant.

ALFALFA

Dodder (Fig. 192)

The presence of dodder causes small areas of alfalfa to die. Around the margins of these areas the ground is covered with a tangled mat of yellow threads that twine closely about the plants and kill them. Infested spots should be closely mowed, and the stubble sprinkled with kerosene, covered with dry hay, and burned. Only seed free from dodder should be used. Samples of seed may be sent to the State Experiment Station at Geneva to be examined for dodder. Alfalfa seed can be cleaned by sifting it through a 20x20-mesh sieve made of No. 34 wire.

FIG. 192.— *Dodder on alfalfa, showing the slender, cord-like stems and the bunches of small white flowers*

FIG. 193.— *Alfalfa leaf spot*

Leaf spot (Fig. 193)

Leaf spot is the most serious fungous disease of the alfalfa crop in the State. It causes the leaves to become spotted and yellow and to fall prematurely. New seeding, if badly diseased, should be topped, *but never mowed closely.* When older fields are attacked, the hay should be cut a few days early in order to avoid loss of leaves and to permit a new growth that will usually outgrow the trouble.

APPLE

Aphid

Three species of plant lice are abundant on the apple: the grain aphid, the green aphid, and the rosy aphid. They all pass the winter in the form of black, shiny eggs on the twigs and branches. The eggs hatch just as the buds are bursting, and the young lice cluster on the opening buds (Fig. 194). Thorough spraying at this time with "black leaf 40" tobacco extract, ¾ pint in 100 gallons of lime-sulfur or water, is the most effective way of controlling these insects. If used with water, 4 or 5 pounds of soap should be added, to make the liquid stick and spread better.

Apple maggot

The small, white apple maggots make brownish, winding burrows in the flesh of the fruit, particularly in summer and early fall varieties. When full-grown the maggot leaves the fruit, passes into the ground, and finally transforms into a fly. The flies are constantly sucking material from the surface of the apples. They may be poisoned by applying a mixture of 2½ pounds of arsenate of lead to 50 gallons of water sweetened with 1½ gallons of cheap sirup. The mixture should be applied to the trees, in coarse drops, between June 15 and July 1, and again in ten days. If rains wash the liquid from the trees, other applications should be made. Well-cultivated orchards seem less subject to the attacks of the maggot, and therefore clean cultivation is recommended.

FIG. 194.—*Apple aphids clustering on opening buds. The most effective time for spraying*

Apple redbug

The apple redbugs are small, bright red, sucking bugs, which appear on the trees and puncture the newly set fruit, causing the apples either to fall or, if they mature, to be knotty, as shown in Fig. 195.

The trees should be twice sprayed with "black leaf 40" tobacco extract, 1 pint in 100 gallons of spray liquid: first, when the blossoms show pink, second, as the last of the petals are falling.

FIG. 195.—*Mature apple, showing injury by redbugs*

Apple tent-caterpillar

The apple tent-caterpillar hibernates in the egg state. The eggs are glued in ring-like, brownish masses (Fig. 196) around the smaller twigs of the trees, where they may be easily found and destroyed. The caterpillars appear in early spring, devour the tender leaves, and build unsightly nests on the smaller branches. The young caterpillars may be killed just as the buds show green, by spraying with lime-sulfur as used for the San José scale. They may also be poisoned with arsenate of lead when the blossoms show pink. The nests may be destroyed by wiping them out when they are small.

FIG. 196.—*Egg mass of apple tent-caterpillar*

Bud moth

The small, brown, black-headed caterpillars of the bud moth devour the tender leaves and flowers of the opening buds in early spring. Two applications of 4 pounds of arsenate of lead in 100 gallons of water should be made, the first when the leaf tips appear and the second just before the blossoms open. If necessary, there should be a third application after the blossoms fall. (For use with lime-sulfur, see page 470.)

Cankerworm

Cankerworms are small measuring worms, or loopers, which defoliate the trees in May and June. The female moths are wingless, and in late fall or early spring crawl up the trunks of the trees to lay their eggs on the branches. A thorough application should be made once or twice, before the blossoms open, of 4 pounds of arsenate of lead in 100 gallons of water. The application should be repeated after the blossoms fall. The ascent of the wingless females should be prevented by means of sticky bands or wire-screen traps.

Case bearer

The small case-bearer caterpillars live in pistol- or cigar-shaped cases about ¼ inch long, which they carry about with them. They appear in spring on the opening buds at the same time as the bud moth and may be controlled by the same means.

Codling moth (Fig. 197)

The pinkish caterpillar of the codling moth causes a large proportion of wormy apples. The eggs are laid by the small moth on the leaves and skin of the fruit.

Most of the caterpillars enter the apple at the blossom end. When the petals fall the calyx is open (Fig. 198), and this is the time to spray. The calyx soon closes and keeps the poison inside ready for the young caterpillar's first meal (Fig. 199). After the calyx has closed it is too late to spray effectively. The caterpillars become full-grown in July and August, leave the fruit, and crawl down on the trunk of the tree, and there most of them spin cocoons under the loose bark. In most parts of the country there are two broods annually.

FIG. 197.— *Codling-moth caterpillar in an apple*

Immediately after the petals fall, the trees should be sprayed with 4 pounds of arsenate of lead in 100 gallons of dilute lime-sulfur. The application should be repeated about three weeks later. (For use with lime-sulfur, see page 470.)

FIG. 198.— *Just right to spray. Two apples from which the petals have just fallen. The calyx lobes are widely spread*

FIG. 199.— *Almost too late to spray effectively. The calyx lobes are nearly together*

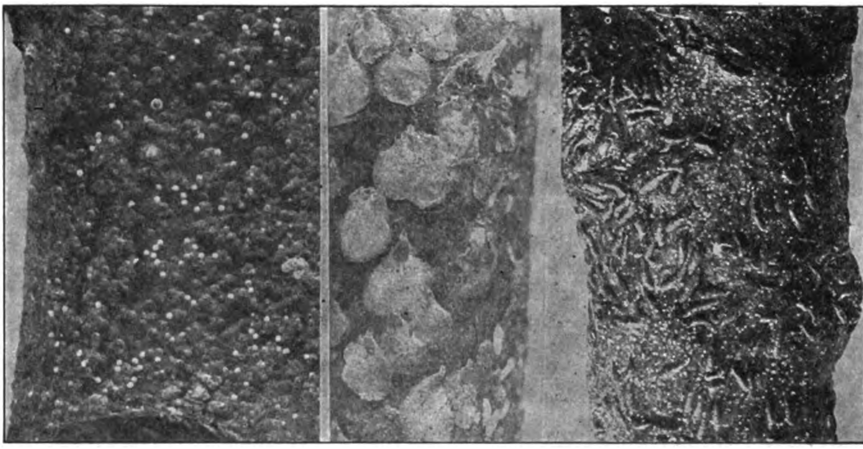
Egg of codling moth on young apple

Fruit-tree leaf-roller

The green, black-headed caterpillars of the fruit-tree leaf-roller attack the opening buds and web together the expanding leaves and blossoms, and eat holes in the young apples. They attack pears also. The insects pass the winter in the egg stage. The eggs are deposited in flat masses on the twigs, and covered with a varnish-like substance. A large proportion of the eggs can be destroyed by a thorough application of a miscible oil, 1 gallon in 15 gallons of water, made just before the buds open. This should always be followed by one or two thorough applications of arsenate of lead, 6 pounds in 100 gallons of water, made soon after the buds open.

Green fruit-worm

When full-grown the caterpillars of the green fruit-worm are somewhat larger than those of the fruit-tree leaf-roller, being about one to one and one-half inches in length and of a light green color with whitish stripes. They injure the fruit in much the same way as does the fruit-tree leaf-roller. They may be controlled by early arsenical sprays as recommended for the leaf roller.



San José scale Scurfy scale Oyster-shell scale

FIG. 200.— *The three common scales infesting the apple*

Leaf blister-mite

The presence of the minute leaf blister-mite is indicated by small, irregular, brownish blisters on the leaves. The trees should be sprayed in late fall or early spring with lime-sulfur of the strength recommended for San José scale.

Round-headed borer

The only practicable method of controlling the round-headed borer is to dig out the insects or kill them with a wire.

San José scale (Fig. 200)

The San José scale is nearly circular in outline and about the size of a pinhead. When abundant it forms a crust on the branches of the tree and causes small red spots on the fruit. It multiplies with marvelous rapidity, there being three or four broods annually, and each mother scale may give birth to several hundred young. The young are born alive and breeding continues until late autumn, when all stages are killed by the cold weather except the tiny, half-grown, black scales, many of which hibernate safely.

The trees should be sprayed thoroughly in the fall after the leaves drop, or in the spring, with lime-sulfur (32° Baumé), 1 gallon in 8 or 9 gallons of water. When the trees are badly infested two applications should be made, one in the fall and the other

in the spring. In case of large old trees, 25-per-cent crude oil emulsion should be applied just as the buds are swelling.

Oyster-shell scale (Fig. 200) The oyster-shell scale is an elongate scale ⅛ inch in length, resembling an oyster shell in shape and often encrusting the bark. Spraying should be done as recommended for San José scale.

Scurfy scale (Fig. 200) The whitish, pear-shaped scurfy scale, about ⅛ inch in length, often encrusts the bark, giving it a scurfy appearance. Spraying should be done as recommended for San José scale.

Fire blight (Fig. 201) Fire blight is the same as pear blight. It usually makes itself manifest on the apple trees in three forms, *blossom blight, twig blight, and blight cankers* on limbs and body. It is caused by bacteria which are distributed by bees, flies, and other insects and is not controlled by spraying. Cutting out and destroying the diseased parts is the chief measure to be taken. A systematic inspection of the trees should be made from one to three times a week during the growing season, all blighted twigs

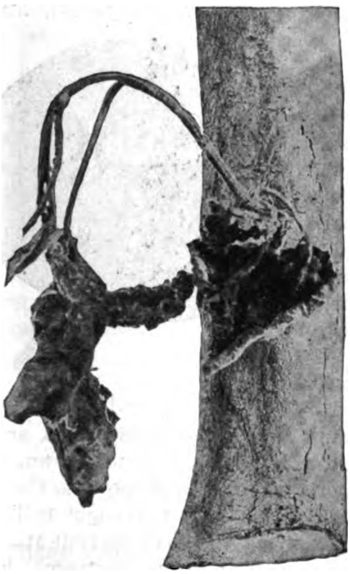


FIG. 201.— *Blight canker of apple*

FIG. 202.— *New York apple-tree canker*

cut out, and *the cuts disinfected* as described below. The bacteria of this disease are carried over winter in cankers on the main limbs and bodies of the trees. All such cankers should be removed with a sharp knife, the cut being made well into the healthy bark, and the wound should be washed with corrosive sublimate, 1 part to 1000 parts of water. The wound should then be painted with coal tar or lead paint. All old pear and apple trees about the premises should be destroyed or cleaned up, because such trees harbor the disease. On older trees of most varieties of apples the infected area does not extend to the older growth. Ordinarily it is impracticable to cut affected twigs from such trees.

New York apple-tree canker (Fig. 202) The New York apple-tree canker is an important fungous disease which should not be confused with the blight canker. These cankers, black and rough, are usually found on the main limbs of old trees, and are very common on Twenty Ounce apples. The fungus causes a brown spotting of the leaves and a black rot of mature fruit. Since the fungus enters through wounds, breaking the bark should be avoided. All wounds made in pruning should be promptly painted over. Cankers should be cut out and treated with coal tar. The body and the limbs of the trees should be soaked when the dormant application for scale is being made.

Frost canker Frost canker, also known as sun scald, is an injury to the bark of trunk and branches, and occurs oftenest on the southwest side of the tree. It is a winter injury believed to be caused by a rapid fall in temperature of tissues that have warmed up on winter days from exposure to sunshine. Collar rot and crotch cankers are also types of winter injury. The dead bark should be removed back to healthy green bark around the injured area, and the wound covered with coal tar or some other good tree paint. The injury should be prevented by endeavoring to ripen the wood early in the fall, and avoiding the exposure of limbs due to removing too many branches in pruning.

Scab (Fig. 203) Scab, commonly known among growers as *the fungus*, attacks both leaf and fruit, but is usually more evident on the fruit. The trees should be sprayed with lime-sulfur 1 to 40 (see table of dilutions page 465), or with bordeaux 3-3-50: first, just before the blossoms open; second, just as the petals fall; third, three weeks after the petals fall. In most seasons the second spraying seems to be the most important. When scab is prevalent and favorable weather for infection prevails, an application should be made in late July to prevent late infection. The spraying should be thorough. For the use of insect poisons with lime-sulfur or bordeaux mixture, see *Bud moth* and *Codling moth* (pages 438 and 439).

FIG. 203.—*Apple scab*

Stippin Stippin is a disease of the fruit known also as bitter pit, and incorrectly as Baldwin spot and as bitter rot, in which brown, corky areas exist beneath the skin and may extend deeply into the flesh. The disease may be detected on the surface as dark pits. It is thought to be due to an improper distribution of water by he sap-carrying vessels of the fruit at a time when it is making rapid growth. The disease sometimes develops in storage, due to rapid changes in temperature. Little is known regarding its control.

APRICOT

(For insect pests, see those under *Peach*, page 453)

ASPARAGUS

Rust Rust is the commonest and most destructive disease of asparagus. It produces reddish or black pustules on stems and branches. All affected plants should be burned late in the fall. The soil should be fertilized liberally and cultivated thoroughly. During the cutting season

no plants should be permitted to mature and all wild asparagus plants in the vicinity should be kept cut. Rust may be partially controlled by spraying with bordeaux 5–5–50, containing a sticker of resin-sal-soda soap (see page 469); but this is a difficult and expensive operation and is probably not profitable except on a large acreage. Spraying should be begun after cutting as soon as the new shoots are from 8 to 10 inches high, and repeated once or twice a week until about September 15. Dusting with sulfur has proved effective in California.

BEAN

Anthracnose, or pod spot (Fig. 204) Anthracnose, or pod spot, is a fungous disease commonly known among growers as *rust*. It is carried over from one season to another in the seed. Only clean seed, obtained by selecting pods free from the diseased spots, should be planted. Hand-sorting of seed and seed treatment will not control this disease, but when the beans can be thoroughly hand-sprayed, bordeaux mixture 5–5–50 will reduce the amount of disease. The first spraying should be done just when the plants break through the ground; the second, when the first pair of leaves are expanded; the third, when the pods have set.

Blight Blight is a bacterial disease. Like anthracnose, blight is carried over in the seed. It is difficult to control. It affects the leaves chiefly, forming large dead areas, and on the pods it forms spots that may be confused with anthracnose. Spraying with bordeaux, as for anthracnose, is said to reduce the injury.

Stem rot Stem rot is a dry rot affecting the part of the stem at and below the surface of the ground, causing affected areas to become reddish in color and to shrivel. This results in vines of low vigor and yield. No satisfactory method of control has been worked out. A wide rotation of crops and good cultural methods have yielded the best results.

FIG. 204.—*Bean anthracnose*

BLACKBERRY

(For insect pests, see those under *Raspberry*, page 460)

CABBAGE AND CAULIFLOWER

Cabbage aphid The cabbage aphids are small, mealy plant lice which are especially troublesome during cool, dry seasons, when their natural enemies are less active. If plants are infested in the seed beds they should be dipped in soap solution before transplanting. As soon as the lice appear they should be sprayed with whale-oil soap, 1 pound in 10 gallons of water, or with one of the tobacco extracts. The application should be repeated when necessary.

Cabbage root-maggot (Fig. 205) The white cabbage root-maggots hatch from eggs laid by a small fly (which somewhat resembles the common house fly) near the plant at the surface of the ground. The earth should be hollowed out slightly around every plant, and carbolic acid emulsion diluted with 30 parts of water applied freely. The treatment should begin early, a day or two after the plants are up or the next day after they are set

out. The application should be repeated every seven to ten days until the latter part of May. It has also been found practicable to protect the plants by the use of tightly fitting cards cut from tarred paper.

FIG. 205.— *Cabbage root-maggots*

In order to protect the plants in the seed bed, the bed may be surrounded with boards from 6 to 8 inches wide placed on edge, and covered tightly with a screen of cheesecloth as soon as the plants begin to appear. In order to harden the plants the cloth should be removed ten days before they are ready to be transplanted.

Cabbage worm (Fig. 206)

The green caterpillars of the cabbage worm hatch from eggs laid by the common white butterfly. There are several broods every season. If the plants are not heading, they should be sprayed with kerosene emulsion or with paris green to which sticker has been added; if they are heading, hellebore should be used.

Black rot

In the bacterial disease known as black rot, the bacteria get into the sap tubes of the leaves, clogging them and

FIG. 206.— *Imported cabbage worms*

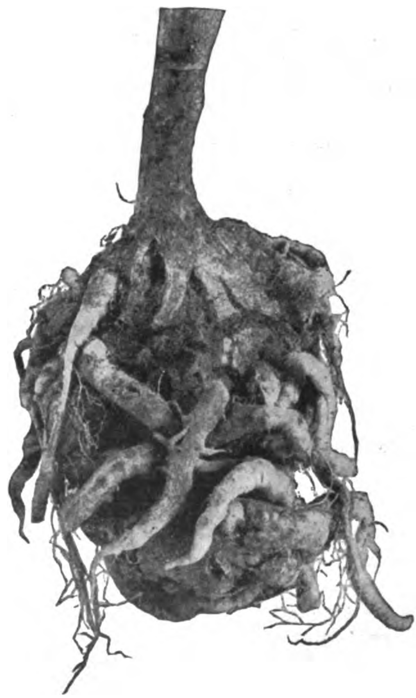


FIG. 207.— *Clubroot of cabbage*

turning them black. The plants drop their leaves and fail to head. Crop rotation should be practiced. The seed should be soaked for fifteen minutes in a solution made by dissolving one corrosive sublimate tablet in a pint of water.

Clubroot, or clubfoot (Fig. 207) Clubroot, or clubfoot, is a slime mold disease, the parasite living in the soil. Crop rotation should be practiced, and *only healthy plants should be set.* Manure containing cabbage refuse should not be used. If the use of infested land is necessary, good stone lime, from 2 to 3 tons per acre, should be applied. The application should be made at least as early as the autumn before planting; eighteen months before planting is better. The seed bed should be limed in the same manner. This disease is sometimes confused with the injury caused by cabbage root-maggots.

CARNATION

Fusarium stem rot Fusarium stem rot is a dry rot of the lower part of the stem. Plants affected by this disease die slowly, usually a branch at a time. The treatment is the same as for Rhizoctonia stem rot.

Leaf spot Round, grayish spots on stem and leaves are evidences of the presence of leaf spot. The treatment is the same as for rust.

Rhizoctonia stem rot The cause of Rhizoctonia stem rot is a soil fungus. The plants wilt suddenly, the stem being affected with soft rot at or below the surface of the soil. In the field the location of the plants should be changed frequently, annually if possible. In the benches sterilized soil, or at least fresh soil, should be used. After transplanting into the greenhouse, the temperature should be kept as low as possible until the plants become established. The soil should be stirred frequently. Overwatering should be avoided.

Rust Rust can be recognized by the brown, powdery pustules on stem and leaves. Only the varieties least affected by this disease should be planted, and only cuttings from healthy plants should be taken. The plants should be sprayed (in the field once a week, in the greenhouse once in two weeks) with copper sulfate, 1 pound to 20 gallons of water. The greenhouse air should be kept as dry and as cool as is compatible with good growth. The foliage should be kept free from moisture, and the plants should be trained so as to secure a free circulation of air among them.

CAULIFLOWER

(See *Cabbage and Cauliflower*)

CELERY

Cerospora leaf blight Cerospora leaf blight is sometimes known as *early blight.* It often appears in the seed bed and becomes destructive early in the summer. It is favored by hot weather, either wet or dry. Plants should be sprayed with bordeaux mixture 5–5–50, from six to eight applications being made, beginning when the plants are set and spraying often enough to keep new growths of leaves covered. Diseased plants and refuse should be destroyed.

Septoria leaf blight, or late blight Septoria leaf blight, or late blight, is a fungous disease often appearing in the seed bed but usually becoming destructive later in the season. It is often destructive after celery is stored. The same treatment as for early blight is used, except that spraying should be continued up to the time when the plants are harvested.

CHERRY

Aphid Early in the season the aphids, dark brown plant lice, curl the terminal leaves, especially attacking sweet cherries. The trees should be sprayed with "black leaf 40" tobacco extract, ¾ pint in 100 gallons of water, to which 4 or 5 pounds of soap is added. The application should be made when the insects are clustered on the opening buds. Repeat the application if necessary.

Cherry fruit flies Cherry fruit flies are small flies with banded wings, which insert their eggs under the skin of the fruit. The maggots burrow in the flesh. These insects are most injurious to late varieties. When the flies first appear in June the trees should be sprinkled with arsenate of lead, 3 ounces in 4 gallons of water sweetened with 1 pint of molasses. The application should be repeated after rains.

Plum curculio — See under *Plum*.

Black knot Black knot is caused by a fungus, the spores of which are carried from tree to tree by the wind and thus spread the infection. The same fungus also affects plums. All knots should be cut out and burned before the leaves appear in spring. Cherry growers should see that the knots are removed from all plum and cherry trees in the neighborhood.

Brown rot of fruit Brown rot of fruit is produced by the same fungus that causes the brown rot of peaches and plums. (See page 453.)

Leaf spot Leaf spot is a fungous disease in which the leaves become thickly covered with reddish or brown spots and fall prematurely. Badly affected trees winterkill. Often the dead spots drop out, leaving clear-cut holes. The trees should be sprayed with lime-sulfur 1 to 50 (32° Baumé) or with bordeaux 5-5-50. The addition of 1½ pounds of iron sulfate to 50 gallons of the diluted lime-sulfur solution decreases the danger of burning, increases the adhesiveness of the material, and affords a marker. Usually four applications should be made: the first, when the fruit is free from the calyx; the second, two weeks later; the third, immediately after picking; the fourth, if necessary, three weeks later.

Powdery mildew Powdery mildew attacks leaves at the tips of the growing shoots, and is often serious on nursery stock. The leaves curl and show the white mealy growth of the fungus. The trees should be dusted heavily with sulfur or sprayed with lime-sulfur solution 1 to 50.

CHRYSANTHEMUM

Septoria leaf spot Septoria leaf spot is a fungous disease. Plants should be sprayed with bordeaux 5-5-50 every ten days, or often enough to protect new foliage. Ammoniacal copper carbonate may be used, but it is not so effective.

Rust For rust the plants should be treated as for Septoria leaf spot. Care should be taken not to wet the foliage when watering.

CUCUMBER, MELON, AND SQUASH

Aphid Dark green plant lice feed on the undersides of the leaves, causing them to curl and wither. The vines should be sprayed with "black leaf 40" tobacco extract, ¾ pint in 100 gallons of water, to which 4 or 5 pounds of soap is added. The application may be repeated if necessary. Spray-

ing can be done more readily and with less material if the vines are trained to run in the rows. It is necessary to thoroughly cover the undersides of the leaves; therefore the sprayer must be fitted with an upturned nozzle. The vines should be burned as soon as the crop is harvested, and all weeds should be kept down.

Squash stinkbug

The rusty-black adult squash stinkbug emerges from hibernation in the spring and lays its eggs on the undersides of the leaves. The nymphs suck the sap from the leaves and stalks, causing serious injury. The adults may be trapped under boards in the spring. The leaves should be examined for the smooth, shining, brownish eggs and these should be destroyed. The young nymphs may be killed with " black leaf 40 " tobacco extract, as recommended for the aphis.

Squash-vine borer

Squash vines are frequently killed by a white caterpillar which burrows in the stem near the base of the plant. The stem should be slit and the borer killed with the knife. A few early squashes should be planted between the rows of the late varieties, as a trap crop. As soon as the early crop is harvested, the vines should be removed and burned. When the vines are long enough they should be covered at the joints with earth, in order to develop secondary root systems for the plant in case the main stem is injured.

Striped cucumber beetle

The yellow, black-striped cucumber beetles appear in numbers and attack the plants as soon as they are up. Early squashes may be planted as a trap crop around the field. The vines should be protected with screens until they begin to run, or kept covered with bordeaux mixture, which will make them distasteful to the beetles.

(See melon diseases under *Melon*, page 451.)

Downy mildew

Downy mildew, the most serious fungous disease of the cucumber, is known among growers as *the blight*. The leaves become mottled with yellow, show dead spots, and then dry up. The vines should be sprayed with bordeaux 5–5–50, beginning when the plants begin to run and repeating the application every ten to fourteen days throughout the season.

Wilt

Wilt is a disease caused by bacteria that get into the sap tubes of the leaf and the stem and clog and destroy them, causing the plant to wilt. The bacteria are distributed chiefly by striped cucumber beetles. The beetles should be destroyed or driven away by thorough spraying with bordeaux 5–5–50. All wilted leaves and plants should be gathered and destroyed. The most that can be expected is that the loss may be slightly reduced.

FIG. 208.—*Currant worms*

CURRANT

Currant worm (Fig. 208)

In the spring the small, green, black-spotted larvæ of the currant worm feed on the foliage, beginning their work

on the lower leaves. There is a second brood in early summer. When the worms first appear, the bushes should be sprayed with 1 pound of paris green or 4 pounds of arsenate of lead in 100 gallons of water. Ordinarily the poison should be combined with bordeaux. (See *Leaf Spot.*) After the fruit is half grown, hellebore should be used.

Cane blight, or wilt

Cane blight, or wilt, is very destructive in the Hudson Valley. The canes die suddenly while loaded with fruit and leaves, as do those attacked by the cane borer. The disease is caused by a fungus that kills the bark in places and discolors the wood. No definite line of treatment has been established, but a good practice is to examine the plantation three or four times every summer, beginning when the plants are small, and cut out and burn all canes showing signs of disease.

Leaf spot and anthracnose (Fig. 209)

Leaf spot and anthracnose is caused by two or three different fungi. The leaves become spotted, turn yellow, and fall prematurely. The disease may be controlled by from three to five sprayings with bordeaux 5–5–50. An application after picking is completed will help to retain the foliage. ***On the first appearance of currant worms, the bushes should be sprayed with bordeaux and paris green,*** 1 pound of paris green to 100 gallons of bordeaux, or with arsenate of lead, 4 pounds to 100 gallons. If a second brood of worms appears the application should be repeated.

FIG. 209.— *Currant leaf spot*

DEWBERRY

(For insect pests, see those under *Raspberry*, page 460)

GINSENG

Alternaria blight (Fig. 210)

Alternaria blight is the most destructive and common disease of cultivated ginseng. In order to prevent its occurrence the surface of the soil should first be sprayed thoroughly with copper sulfate solution, 1 pound to 10 gallons, early in the spring before the plants appear, and then sprayed with bordeaux 3–3–50 as soon as the plants begin to break through the soil. Spraying should be done re-

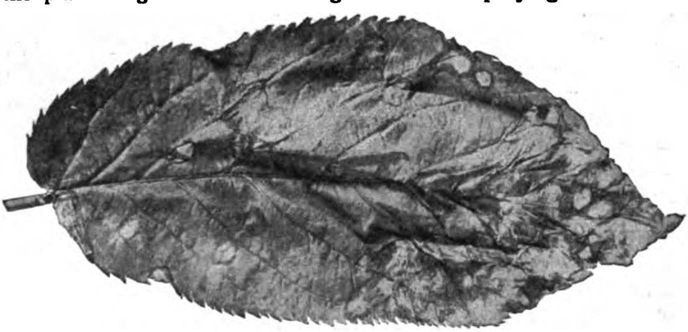


FIG. 210.— *Alternaria blight of ginseng*

peatedly while the plants are coming through the soil, special effort being made to spray the stems, since it is on these that the disease first becomes established in the spring. The plants should be kept thoroughly covered with the spray throughout the season. The seed heads should be sprayed thoroughly just after the blossoms fall, and again when the berries are two-thirds grown, in order to prevent blast caused by the Alternaria fungus. Diseased tops should be destroyed.

Mildew Mildew attacks tops shortly after they come up. The plants should be sprayed early with bordeaux.

Root rots Root rots are caused by various fungi and are favored by wet, soggy soils. The soil should be thoroughly drained.

Wilt Wilt is a disease caused by a fungus in the sap tubes of the root. It may be checked by removing the wilted plants as soon as they are discovered.

GOOSEBERRY

Powdery mildew The fruit and leaves of gooseberry bushes attacked by powdery mildew are covered with a dirty white growth of fungus. The disease is severe on European varieties. In setting a new plantation, a site should be chosen where the land is well underdrained and where there is a good circulation of air. Drooping branches should be cut away. The ground underneath should be kept free from weeds. When the first evidence of mildew appears, the bushes should be sprayed thoroughly with lime-sulfur solution (32° Baumé) diluted 1 to 40, and the spraying should be repeated as often as necessary. From one to five applications may be required.

GRAPE

Flea beetle, or steely beetle The small, shining, blue flea beetles appear in early spring and eat into the opening buds. The brown larvæ feed on the leaves in May and June. When the beetles appear, they should be handpicked into a pan containing a little kerosene. To kill the larvæ on the leaves from May 15 to July 1, 1 pound of paris green or 4 pounds of arsenate of lead should be added for every 100 gallons of bordeaux (see under *Black rot*) and the bushes should be sprayed with this mixture.

Leaf hopper The small, yellowish leaf hoppers, erroneously called *thrips*, suck the sap from the undersides of the leaves, causing them to turn brown and dry up. The leaves should be sprayed very thoroughly on the underside with "black leaf 40" tobacco extract — ¾ pint in 100 gallons of water, to which 4 or 5 pounds of soap is added—about July 1, to kill the young leaf hoppers. The application should be repeated in a week or ten days.

Rootworm (Fig. 211) The small, white grubs of the rootworm feed on the roots, often killing the vines in a few years. The adults are small, grayish brown beetles, which eat peculiar chain-

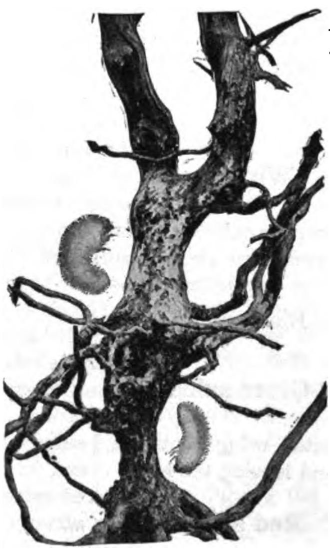


FIG. 211.—*Grape rootworm*

like holes in the leaves during July and August. The vines should be cultivated thoroughly in June, especially close around them so as to kill the pupæ in the soil. The vines should be sprayed thoroughly, about a week after the first beetles appear, with arsenate of lead, 6 pounds in 100 gallons of water sweetened with 2 gallons of molasses. The application should be repeated in a week or ten days.

Rose chafer The ungainly, long-legged, grayish rose chafers are found in sandy regions and often swarm into vineyards and destroy the blossoms and foliage. The vines should be sprayed thoroughly with arsenate of lead, 8 pounds in 100 gallons of water sweetened with 2 gallons of molasses. The application should be repeated if necessary.

Black rot Black rot is the most destructive fungous disease of grapes in this State. It is carried over from one season to the next chiefly in old rotted berries or mummy fruits that fall to the ground or cling to the vines. All mummies that cling to the arms at trimming time should be removed. The soil should be plowed early, all mummies and diseased leaves being turned under. All refuse should be raked under the vine into the last furrow and covered with the grape hoe. This work cannot be done too thoroughly. The vines should be sprayed four times with bordeaux mixture 4-4-50: first, when the shoots are ten inches long; second, just as soon as the blossoming period is over; third, when the berries are the size of peas; fourth, from two to three weeks later. Infections take place with each rain throughout the growing season. The foliage should be protected by a coating of the spray *before* every rain. The new growth, especially, should be well sprayed. When the foliage becomes dense the clusters should be sprayed with a trailer, or hand-spraying device. (For use of insecticides in bordeaux, see under *Flea beetle*.)

Downy mildew Downy mildew is a fungous disease most evident on the leaves, making large brown spots on the upper surface with white downy growth beneath. It also attacks the green fruit, causing what is known to growers as *hard white berry*. Bordeaux as applied for black rot will control this disease. In very rainy seasons an additional application may be necessary. In preparing the bordeaux mixture the ferrocyanide test (page 467) should be used, and only enough milk of lime should be added to neutralize the copper sulfate. This will prevent spotting on early-maturing varieties.

GREENHOUSE INSECTS

White fly The nymphs of the white fly are small, greenish, scale-like insects found on the undersides of the leaves; the adults are minute, white, mealy, winged flies. Plants should be sprayed with whale-oil soap or tobacco extracts; or, if the insects are infesting cucumbers or tomatoes, the greenhouse should be fumigated overnight with hydrocyanic acid gas, using 1 ounce of potassium cyanide to each 1000 cubic feet of space.

Black aphid The black aphid is harder to kill than the green aphid, but may be controlled by the same methods.

Green aphid Plants infested with green aphids should be sprayed with tobacco extract when practicable, or fumigated with one of the tobacco preparations. If violets are infested, the house should be fumigated, using from ⅛ to ¼ ounce of potassium cyanide for each 1000 cubic feet of space, and leaving the house closed for from one-half to one hour.

Red spider The red spider may be controlled by syringing off the plants with clear water two or three times a week, care being taken not to drench the beds.

Violet gallfly Violets grown under glass are often greatly injured by a very small maggot, the larva of the violet gallfly, which causes the edges of the leaves to curl, turn yellowish, and die. The adult is a minute fly resembling a mosquito. Infested leaves should be picked off and destroyed as soon as discovered. Fumigation is not advised for this insect or for red spider.

LETTUCE

Drop, or rot Drop, or rot, is a fungous disease often destructive in greenhouses, discovered by the sudden wilting of the plants. It is completely controlled by steam sterilization of the soil to the depth of two inches or more. If it is not feasible to sterilize the soil, fresh soil should be used for every crop of lettuce. The surface soil should be kept loose and dry. When the plants shade the ground, much less water should be used.

MELON

(For insect pests, see *Cucumber, Melon, and Squash*, page 446)

Anthracnose Anthracnose appears as a spotting of leaves, and as dark, sunken pits in the fruit which may become so numerous and large that the fruit decays. Salmon-colored, pasty masses may be seen in the older spots. These consist of innumerable spores of the fungus, which are readily disseminated in wet weather. Vines should be sprayed with bordeaux 5-5-50 several times in the course of the growing season.

Downy mildew Downy mildew is commonly called *blight* and is a very injurious disease. The leaves show angular, dead, brown spots, and then dry up and die; the fruit often fails to ripen and lacks flavor. The disease is caused by the same fungus as is the downy mildew of cucumbers. No effective method of control is known. While bordeaux has proved effective in controlling the downy mildew on cucumbers, it seems to be of little value in fighting the same disease on melons.

Wilt The bacterial disease of the muskmelon known as wilt is the same as the wilt of cucumbers. The same treatment is given.

NURSERY STOCK

Fire blight Fire blight of nursery stock is the same disease as that described under *Apple* and *Pear*. It affects apples, pears, quinces, and hawthorns. Sources of infection, such as old infested apple and pear trees, should be cleaned out. Frequent regular inspections of stock should be made during the growing period, and all infected twigs should be removed and destroyed. All cut surfaces should be disinfected with corrosive sublimate solution.

Leaf spot Leaf spot, known also as *yellow leaf* and as *shot hole*, is a disease causing a spotting, yellowing, and dropping of cherry leaves and a spotting of plum leaves. The diseased area often falls out, giving the leaves a perforated appearance described as *shot hole*. Control consists in plowing under old leaves early in the spring, and in making from five to seven applications of lime-sulfur solution (32° Baumé) diluted 1 gallon to 50 gallons of water. (See *Cherry leaf spot*.)

Plant lice Plant lice on nursery stock may be controlled by dipping the tips of the plants in whale-oil soap, 1 pound in 5 gallons of water, or in one of the tobacco extracts.

San José scale Nursery stock which has been grown in nurseries infested with San José scale should be fumigated with hydrocyanic acid gas after the trees are dug, using 1 ounce of potassium cyanide for every 100 cubic feet of space. The fumigation should be continued for from one-half to three-quarters of an hour. The trees should not be fumigated when they are wet, since the presence of moisture renders them liable to injury.

OATS

Smut (Fig. 212) The commonest and most destructive disease of oats is smut, carried over from one season to the next by the fungus spores on the seed. It may be entirely prevented by treating the seed oats, before planting, with a solution of formalin, 1 pint to 45 or 50 gallons of water. The oats are placed on a clean floor and the formalin is sprinkled on them as they are shoveled over, using one gallon of the solution to a bushel of oats. The oats should be mixed thoroughly, then shoveled into a pile and covered with blankets or canvas. After standing in the pile for from two to four hours, the oats, if they are to be drilled, should be spread out to dry; or they may be sown by hand without drying. One extra peck of seed for each bushel used should be allowed for swelling of the grain. Treatment once in three years is usually sufficient to prevent material loss from smut.

FIG. 212.— *Oat smut*

ONION

Onion maggot For control of the onion maggot, see carbolic-acid-emulsion treatment under *Cabbage root-maggot.*

Onion thrips Onion tops frequently turn white and die as the result of the feeding punctures caused by the minute yellowish onion thrips. The injury is known as *white blast.* The plants should be sprayed thoroughly with whale-oil soap, 1 pound in 4 gallons of water, or with "black leaf 40" tobacco extract, 1 pint in 100 gallons of water to which 4 or 5 pounds of soap is added.

Mildew Onion mildew, or blight as it is commonly called, is a fungous disease much like the blight of potatoes. The plants should be sprayed with bordeaux 5-5-50, beginning when they show three leaves and repeating every ten days until the crop is harvested. One gallon of sticker (see page 469) should be added to every 50 gallons of the mixture. It is useless to begin spraying after the disease appears.

Smut Smut can be detected by the black pustules on leaves and bulbs. It is harmful only where onions are grown extensively. It may attack the seedlings, killing them outright, or may appear on mature bulbs in the fall. Onions from sets or those started in clean soil and transplanted are not affected. Crop rotation should be practiced. When planting seed, 100 pounds of sulfur and 50 pounds of air- laked lime mixed, per acre, should be drilled into the rows; or the seed should be sprinkled, as it lies in the row before covering, with a solution of formaldehyde, 1 pint to 30 gallons of water. This may be applied with a drip attachment to the drill, or with a sprinkling can.

PEACH

Peach borer (Fig. 213)

The adult peach borer is a clearwing moth. The larva burrows just under the bark near or beneath the surface of the ground; its presence is indicated by a gummy mass at the base of the tree. The borers should be dug out in June and the trees mounded up. At the same time gas tar or coal tar should be applied to the trunk from the roots up to a foot or more above the surface of the ground.

FIG. 213.—*Peach borer*

Plum curculio—See under *Plum*.
San José scale—See under *Apple*.

FIG. 214.— *Mummies on peach tree, the result of brown rot*

Brown rot (Fig. 214)

Brown rot is a serious fungous disease of stone fruits, and one of the most difficult to control. The trees should be pruned so as to let in sunlight and air, and the fruit should be well thinned. The trees should be sprayed with self-boiled lime-sulfur 8–8–50 (see page 468), to which 2 pounds of arsenate of lead to 50 gallons of the liquid is added. The first spraying should be done about the time when the shucks are dropping from the young fruit; the second, from two to three weeks after the first, using the same combinations as for the first; the third, about one month before the fruit ripens, with self-boiled lime-sulfur 8–8–50, omitting the arsenate of lead.

Black spot, or scab (Fig. 215)

Black spot, or scab, often proves injurious in wet seasons, and particularly in damp or sheltered situations. While this disease attacks twigs and leaves also, it is most conspicuous and injurious on the fruit, where it appears as dark spots or blotches. In severe infestations the fruit cracks. In the treatment of this disease it is of prime importance *to secure a free circulation of air about the fruit.* This may be accomplished by avoiding low sites, by pruning, and by removal of windbreaks. The trees should be sprayed with self-boiled lime-sulfur 8–8–50, applied at the same time as for brown rot.

Leaf curl Leaf curl is a fungous disease in which the leaves become colored, swollen, and distorted in spring, and drop in June and July. Elberta is an especially susceptible variety. The disease is easily and completely controlled by spraying the trees once, *before the buds swell*, with bordeaux 5–5–50, or with the lime-sulfur solutions used for San José scale (see under *Insecticides*, page 464).

FIG. 215.— *Black spot on peach*

Mildew Mildew is a white, powdery growth on young leaves and tips of shoots, often spotting fruit. Trees should be sprayed with self-boiled lime-sulfur or dusted with sulfur.

Yellows Yellows is a so-called physiological disease. Its cause is unknown. It is contagious, and is serious in some localities. It is known by the premature ripening of the fruit, by red streaks and spots in the fruit flesh, and by the peculiar clusters of sickly, yellowish shoots that appear on the limbs here and there. Eradication is the only means of control. Diseased trees should be dug out and burned as soon as discovered.

PEAR

Codling moth — See under *Apple*.

False tarnished plant bug The false tarnished plant bugs are small, green, sucking insects, which puncture the newly set pears causing them to become knotty (Fig. 216) and rendering them gritty. The trees should be sprayed thoroughly with "black leaf 40" tobacco extract — ¾ pint in 100 gallons of water, to which 4 or 5 pounds of soap is added — just as the last of the petals are falling. The application should be repeated a few days later.

FIG. 216.—*Pear injured by the false tarnished plant bug*

Leaf blister-mite See under *Apple*. On pears lime-sulfur has also been found effective.

Pear psylla Pear psyllas are minute, yellowish, flat-bodied, sucking insects, which are often found working in the axils of the leaves and in the fruit early in the season. They develop into minute, cicada-like, jumping lice. The young psyllas secrete a large quantity of honeydew, in which a peculiar black fungus grows, giving the bark a characteristic sooty appearance. There may be four broods annually and the trees are often seriously injured. The trees should be sprayed for the adult psyllas, in a warm spell in December or March, with "black leaf 40" tobacco extract, ¾ pint to 100 gallons of water with 5 pounds of whale-oil soap added. The trees should be sprayed for the eggs, just before the blossom clusters open, with lime-sulfur at scale strength. They should be sprayed for the young psyllas, after the blossoms fall, with "black leaf 40" tobacco extract, ¾ pint to 100 gallons of water with 5 pounds of soap added. The application may be repeated if necessary.

Pear slug (Fig. 217) The small, slimy, dark green pear slugs skeletonize the leaves in June. A second brood appears in August. The trees should be sprayed thoroughly with 4 pounds of arsenate of lead in 100 gallons of water.

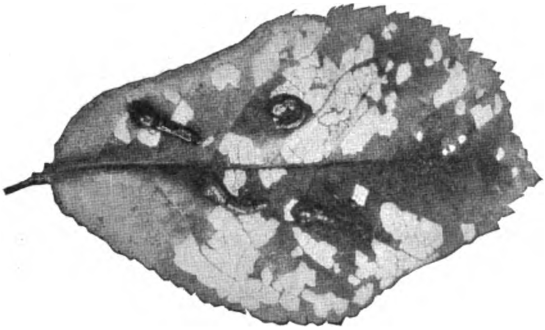


FIG. 217.— *Pear slugs skeletonizing a leaf*

San José scale—See under *Apple*.

Fire blight The fire blight of pears is the same disease as the fire blight of apples, but it is more destructive to pears. It kills the twigs and the branches, on which the leaves suddenly blacken and die but do not fall. It also produces cankers on the trunk and large limbs. Blighted branches should be pruned out as soon as discovered, cutting from 6 to 8 inches below the lowest evidences of the disease, and disinfecting with corrosive sublimate solution 1 to 1000. Limb and body cankers should be cleaned out as described for fire blight on apple trees. All large wounds should be disinfected and covered with a coat of paint or gas tar.

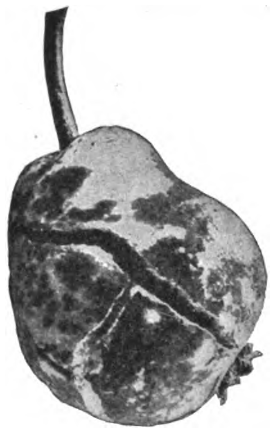


FIG. 218.— *Pear scab*

Scab (Fig. 218) Scab is a fungous disease very similar to apple scab, but not the same. It is very destructive to some varieties of pears, as, for example, Flemish and Seckel. The trees should be sprayed three times with bordeaux 3–3–50, as for apple scab (page 442).

PLUM

Plum curculio (Fig. 219) The adult plum curculio is a small snout-beetle, which inserts its eggs under the skin of the fruit and then makes a characteristic crescent-shaped cut beneath it. The grub feeds within the fruit and causes it to drop. When full-grown the grub enters the ground, changing in late summer to the beetle, which finally goes into hibernation in sheltered places. Trees should be sprayed just after the blossoms fall with arsenate of lead, from 6 to 8 pounds in 100 gallons of water, the application being repeated in about a week.

FIG. 219.—*Beetle of plum curculio. Enlarged*

Black knot Black knot of plums is the same disease as black knot of cherries and is controlled in the same way (page 446).

Brown rot (Fig. 220) Brown rot of plums is the same disease as brown rot of peaches and should be treated in the same way (page 453).

Leaf spot

Leaf spot of plums is the same as leaf spot of cherries and may be controlled by two or three applications of self-boiled lime-sulfur, or, except in the case of Japanese varieties, which are somewhat resistant to the disease, of lime-sulfur solution diluted 1 to 50. The first application should be made about ten days after the blossoms fall, and the others at intervals of about three weeks.

FIG. 220.— *Brown rot on plum*

POTATO

Colorado potato beetle

The yellow-striped Colorado potato beetle emerges from hibernation in the spring and lays masses of orange-colored eggs on the undersides of the leaves. The larvæ are known as *slugs* and *soft-shells*, and cause most of the injury to the vines. They may be killed by spraying with paris green, 1 pound in 100 gallons of bordeaux mixture. It may sometimes be necessary to use a greater strength of the poison, particularly on the older slugs.

Flea beetle

The small black flea beetles riddle the leaves with small holes and cause them to die. Bordeaux mixture as applied for potato blight protects the plants by making them distasteful to these beetles. (See under *Late blight.*)

Black leg

Black leg is a bacterial disease affecting the vine and sometimes causing a dark-colored decay of the tuber. The stems become black and shrunken at the base, causing the vine to have an unhealthy yellowish appearance. Diseased plants should be eliminated from the field; no diseased, bruised, cracked, nor decayed tubers should be used for planting; and the seed should be treated with corrosive sublimate or formaldehyde.

FIG. 221.— *Early blight of potato*

Common scab

Scab is caused by a fungus that attacks the surface of the tubers. It is carried over on diseased tubers and in the soil. Tubers should be treated before cutting by soaking in formalin solution, 1 pint to 30 gallons of water, for two hours, or in corrosive sublimate, 1 ounce to 7½ gallons of water, for one and one-half hours. They should be planted in clean soil. In general, when land becomes badly infested with scab it is best to plant it with other crops for several years. The application of lime or wood ashes to potato soil should be avoided.

Early blight (Fig. 221)

Early blight is a fungous disease, showing as a leaf spot, which may be so severe as to cause vines to die. Affected

vines produce small tubers and consequent low yield. Vines should be sprayed with bordeaux 5-5-50.

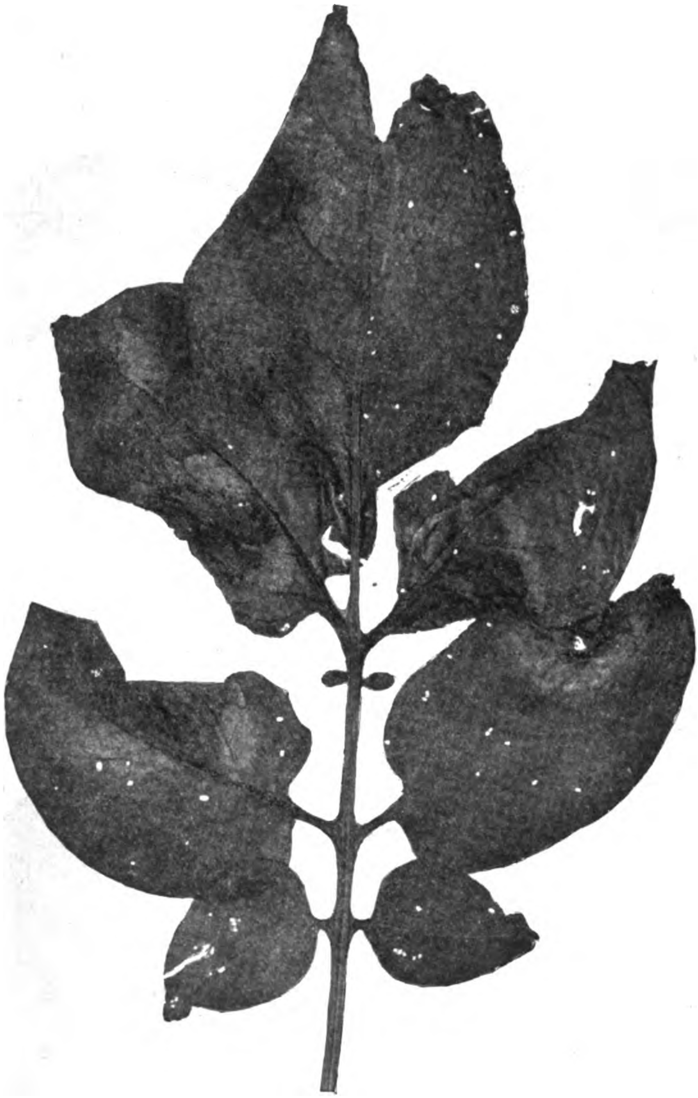


FIG. 222.— *Potato leaves affected by the late blight.* (*Photograph by New York Agr. Exp. Sta., Geneva*)

Late blight (Figs. 222-223) Late blight is a fungous disease showing as a leaf blight and as a dry rot of tubers. Sometimes the tuber rot does not show until after storage. The late blight is often confused with tipburn, arsenical injury, or flea-beetle injury. The plants should be sprayed from five to eight times with bordeaux 5-5-50, beginning when the vines are six inches

high and continuing throughout the growing season. Late spraying on late varieties is especially necessary.

Fusarium dry rot (Fig. 224) Fusarium dry rot is a storage dry rot, in which the decay extends to the center of the tuber, the affected area at the surface having a wrinkled, sunken appearance, often with numerous white tufts of mold breaking through. Selecting clean tubers for planting, seed treatment, and care in handling the crop, will reduce the amount of this rot.

FIG. 223.— *Cross section of a potato tuber affected by blight rot*

FIG. 224.— *Fusarium dry rot of potato tuber*

Physiological vine diseases Physiological vine diseases, such as curly dwarf, leaf roll, and mosaic, cause great reduction in yield. The name is descriptive of each of these. The diseases are transmitted by means of seed tubers. Selection of healthy vines in the field is the only known method of eradication.

FIG. 225.— *Powdery scab on potato tuber*

FIG. 226.— *Sclerotia of Rhizoctonia on potato tuber*

Powdery scab (Fig. 225) Powdery scab, recently discovered as occurring in this State, is a slime mold disease affecting the tubers. It appears first as small, discolored pimples, which enlarge and break through the skin,

forming pustules filled with brown powder, the spores of the organism. The infected areas are quarantined. No tubers from infected fields should be planted. A wide rotation of crops and seed treatment aid in control.

Rhizoctoniose (Figs. 226-227) Rhizoctoniose is a fungous disease showing as numerous black bodies of various sizes on the surface of tubers, and as reddish brown cankers on young sprouts, which often die. The disease is said to bring about also a rosetting of the vines and the production of many small tubers near the surface of the soil. Crops should be rotated and seed tubers should be treated with corrosive sublimate.

Tipburn Tipburn is a dying and blackening of the tips and the margins of leaves, caused by hot, dry weather following favorable conditions for growth. Good cultural practices, combined with thorough spraying as for late blight, will materially reduce the amount of injury.

Wilt Wilt is a disease produced by either of two fungi which cause a wilting and dying of the lower leaves and a discoloration of the sap vessels of vine and tuber. This shows in the tuber as a dark ring on the surface of a slice across the stem end. Diseased tubers should be rejected and crop rotation should be practiced. Much progress can be made by field selection.

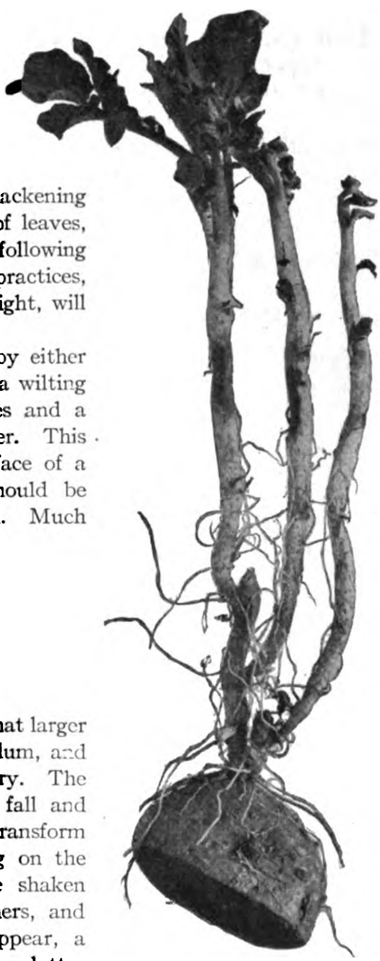


FIG. 227.— *Rhizoctoniose on young shoots of potato*

PRUNE

(For insect pests, see *Plum*)

QUINCE

Quince curculio The quince curculio is somewhat larger than that which infests the plum, and differs from it in its life history. The grubs leave the fruits in the fall and enter the ground, where they hibernate and transform to adults the next May, June, or July, depending on the season. When the adults appear they may be shaken from the trees onto sheets or curculio catchers, and destroyed. In order to determine when they appear, a few trees may be shaken daily, beginning the latter part of May. Good results are sometimes obtained in reducing the amount of infestation by picking off and destroying all infested fruit about a month before picking time, thus leaving on the trees only first- and second-class quinces.

Round-headed apple-tree borer — See under *Apple*.

San José scale — See under *Apple*.

Fire blight

Fire blight of quinces is the same disease as fire blight of pears (page 455). Affected branches should be cut out and the wounds disinfected with corrosive sublimate. Sources of infection should be cleaned up.

Leaf and fruit spot (Fig. 228)

Leaf and fruit spot is a fungous disease producing round, reddish brown spots on the leaves and fruit. The trees should be sprayed three times with bordeaux, as for apple and pear scab.

FIG. 228.— *Fruit spot on quince*

RASPBERRY

Cane borer

The larva of the cane borer is a grub that burrows down through the canes, causing them to die. In laying her eggs, the adult beetle girdles the tip of the cane with a ring of punctures, causing it to wither and droop. In midsummer the drooping tips should be cut off and destroyed.

FIG. 229.— *Raspberry anthracnose*

Sawfly

The greenish, spiny larvæ of the sawfly feed on the tender leaves in spring. The bushes should be sprayed with paris green or arsenate of lead, or hellebore should be applied.

Anthracnose (Fig. 229)

Anthracnose is very destructive to black raspberries and to the purple variety Columbian, but is not often injurious to the red varieties. It is detected by the circular or elliptical, gray, scab-like spots on the canes. Young plants should not be taken from diseased plantations. All old canes and badly diseased new ones should be removed as soon as the fruit is gathered. Weeds should be kept down. Spraying with bordeaux 4–4–50 will control the disease. The first application should be made when the new canes are from six to eight inches high, and should be followed with two additional applications at intervals of from ten to fourteen days.

Cane blight, or wilt

Cane blight, or wilt, is a destructive disease affecting both red and black varieties. Fruiting canes suddenly wilt and die. The disease is caused by a fungus that attacks the cane at some point and kills the bark and the wood, thereby causing the parts above to die. No successful method of treatment is known. In making new settings only plants from healthy plantations should be used. The fruiting canes should be removed as soon as the fruit is gathered.

Crown gall, or root knot

Crown gall, or root knot, is often destructive, particularly to the red varieties. It is detected by the large, irregular knots on the roots and at the crown underground. It is a contagious disease. *Plants showing root knots should never be set.* Planting on infested land should be avoided. The same disease occurs on peaches.

Red rust Red rust is often serious on black varieties, but does not affect red ones. It is the same as red rust of blackberry. Infected plants should be dug up and destroyed.

ROSE

Aphid and leaf hopper (Fig. 230) The green aphids, or plant lice, usually work on buds, and the yellow leaf hoppers feed on the leaves. The bushes should be sprayed, whenever necessary, with "black leaf 40" tobacco extract, 1 ounce to 6½ gallons of water in which ¼ pound of ordinary laundry soap has been dissolved.

FIG. 230.— *Rose aphids, or plant lice*

Rose chafer — See under *Grape.*

Rose slug — See *Pear slug.*

Black leaf spot Black leaf spot is one of the commonest diseases of the rose. It causes the leaves to fall prematurely. The bushes should be sprayed with bordeaux 5–5–50, beginning as soon as the first spots appear on the leaves. Two or three applications at intervals of ten days will very largely control the disease. Ammoniacal copper carbonate may be used on roses grown under glass. Applications should be made once a week until the disease is under control.

Mildew Mildew is a surface-feeding fungus and is killed by the fumes of sulfur. For greenhouse roses, the steam pipes should be kept painted with a paste made of equal parts of lime and sulfur mixed with water. Outdoor roses that become infested with mildew may be dusted with sulfur or sprayed with a solution of potassium sulfide, 1 ounce to 3 gallons of water. The plants should be sprayed or dusted with the sulfur two or three times, at intervals of a week or ten days.

SQUASH

(See *Cucumber, Melon, and Squash,* page 446)

STRAWBERRY

White grub (Fig. 231) The large, curved, white grubs that attack the roots of strawberry plants are the larvæ of the common June beetles. They live in the ground, feeding on the roots of grasses, weeds, and the like. They should be dug out from beneath infested plants. Cultivation in early fall of land intended for planting will destroy many of the pupæ.

FIG. 231.— *White grub*

Leaf spot Leaf spot is the commonest and most serious fungous disease of the strawberry. It is called also *rust* and *leaf blight.* The leaves show spots which are at first of a deep purple color, but later enlarge

and the center becomes gray or nearly white. The fungus passes the winter in the old diseased leaves that fall to the ground. In setting new plantations, all diseased leaves should be removed from the plants before they are taken to the field. Soon after growth begins, the newly set plants should be sprayed with bordeaux 5-5-50. Three or four additional applications should be made during the season. The following spring, the spray should be applied just before blossoming and again from ten to fourteen days later. If the bed is to be fruited a second time, the plants should be mowed down and the beds burned over as soon as the fruit is gathered.

TOMATO

Blossom end rot

Blossom end rot is a sunken dry rot becoming black at the blossom end of the fruit. It is not a parasitic disease. It may be brought on by a sudden check in the water supply and also by continued successive waterings. It may be somewhat reduced by avoiding heavy applications of stable manure, and by practicing good cultural methods in order to conserve moisture and afford a more uniform supply to the plants throughout the season.

Leaf spot

Leaf spot is the most destructive foliage disease of the tomato in the State. It is a fungous disease, and its distinguishing character is that it begins on the lower leaves and works toward the top, killing the foliage as it goes. It is controlled with difficulty because it is carried over winter in the diseased leaves and tops that fall to the ground. When setting out plants, all the lower leaves that touch the ground should be pinched off; also any leaves that show suspicious-looking dead spots. The disease often starts in the seed bed. The plants should be sprayed very thoroughly on the undersides of the leaves with bordeaux 5-5-50, beginning as soon as they are set out and repeating the application every week or ten days.

TURNIP

Clubroot

Clubroot is the same disease as the clubroot of cabbage. The same treatment is effective.

Soft rot

Soft rot is a bacterial disease, the same as soft rot of cabbage. Planting should be on soils free from the disease, and varieties especially susceptible should not be used. The white turnip seems to be more susceptible than the yellow varieties.

WHEAT

Loose smut

Loose smut is conspicuous in the field at heading time. Both grain and chaff are attacked and transformed into a loose black powder, most of which is blown away by harvest time, leaving the stalk bare. The disease is common and destructive; in 1907 the average loss in New York was at least 10 per cent. This smut is not controlled by treatment with formaldehyde or other chemicals, but should be prevented by treating the seed with hot water as explained on page 469. Seed from fields known to have been free from smut should be used.

Stinking smut

Stinking smut is not readily detected until harvest time. The affected heads appear nearly normal, only the kernels being attacked. The diseased kernels are composed of a brown, foul-smelling powder. They may be crushed easily between the thumb and the finger. The disease may be readily controlled by treating the seeds with formaldehyde solution — 1 pint to 45 gallons of water — immersing them in the solution long enough to skim off the smutted kernels, which rise to the surface, and then spreading them out and drying them.

SPRAY MATERIALS

INSECTICIDES

Arsenate of lead

Arsenate of lead can be applied in a stronger mixture without injuring the foliage than can other arsenical poisons. It is therefore much used against beetles and other insects that are hard to poison. It is bought in the form of a paste or a powder. The paste should be mixed thoroughly with a small amount of water before placing in the sprayer; otherwise the nozzles will clog. The powder may be applied dry or mixed with water. Arsenate of lead may be safely used with bordeaux or lime-sulfur. It is used in strengths varying from 4 to 10 pounds per 100 gallons, depending on the kind of insect to be killed.

Paris green

Paris green is used in varying strengths, depending on the insect to be controlled and the kind of plant treated. The powder is mixed into a paste and then added to the water. The mixture should be kept thoroughly agitated while spraying. If for use on fruit trees, 1 pound of quicklime should be added for every pound of paris green, to prevent burning the foliage. For potatoes paris green is frequently used alone, but it is much safer to add the lime. Paris green and bordeaux mixture may be combined without lessening the value of either, and the caustic action of the arsenic is thus prevented; but it is unsafe to use paris green with lime-sulfur.

Hellebore

For wet application fresh white hellebore should be used, 4 ounces to 2 or 3 gallons of water. For dry application 1 pound of hellebore to 5 pounds of flour or air-slaked lime should be used. Hellebore is a yellowish white powder made from the roots of the white hellebore plant. It loses its strength after a time and should be used fresh. It is employed as a substitute for the arsenical poisons on plants or fruits soon to be eaten.

Kerosene emulsion

Kerosene emulsion is composed of ½ pound of hard, soft, or whale-oil soap, 1 gallon of water, and 2 gallons of kerosene. The soap is dissolved in hot water; this is then removed from the fire, and while it is still hot the kerosene is added. The liquid should be pumped back into itself for five or ten minutes or until it becomes a creamy mass. If properly made the oil will not separate on cooling

For use on dormant trees, the emulsion should be diluted with from 5 to 7 parts of water; for killing plant lice on foliage, with from 10 to 15 parts of water. Crude oil emulsion is made in the same way by substituting crude oil in place of kerosene. The strength of oil emulsions is frequently indicated by the percentage of oil in the diluted liquid, as follows:

For a 10-per-cent emulsion, 17 gallons of water is added to 3 gallons of stock emulsion
For a 15-per-cent emulsion, 10⅓ gallons of water is added to 3 gallons of stock emulsion
For a 20-per-cent emulsion, 7 gallons of water is added to 3 gallons of stock emulsion
For a 25-per-cent emulsion, 5 gallons of water is added to 3 gallons of stock emulsion

Carbolic acid emulsion

Carbolic acid emulsion is composed of 1 pound of soap, 1 gallon of water, and 1 pint of crude carbolic acid. The soap is dissolved in hot water, the carbolic acid is added, and the mixture is agitated into an emulsion. For use against root maggots, the emulsion should be diluted with 30 parts of water.

Tobacco preparation

Nicotine is the poisonous principle of tobacco. It is a powerful contact insecticide. It is now most widely used in the form of nicotine sulfate, a non-volatile liquid, and is usually found in the market in the form of a solution containing 40 per cent of nicotine

or about 52 per cent of nicotine sulfate. When used for plant lice or similar soft-bodied insects it is diluted with from 800 to 1000 parts of water; that is, from ¾ to 1 pint is used in 100 gallons of water. The efficiency of the poison is greatly increased by the addition of from 4 to 5 pounds of soap to each 100 gallons of the liquid; the soap makes the material spread and stick better. Nicotine sulfate can be combined with either bordeaux mixture or lime-sulfur and arsenate of lead, without decreasing the efficiency of the spray.

Nicotine is also used for fumigating greenhouses, either by smudging with damp tobacco stems or by evaporating a nicotine extract in which the nicotine is not in the sulfate form. There are also on the market various kinds of punks and papers containing nicotine and designed for fumigation.

Soaps

Whale-oil soap is an effective insecticide for plant lice. It is dissolved in hot water and diluted so as to obtain 1 pound of soap to every 5 or 10 gallons of water. This strength is effective against plant lice and similar soft-bodied insects. Homemade soaps and good laundry soaps, such as ivory soap, are often as effective as whale-oil soap.

Miscible oils

There are now on the market a number of preparations of petroleum and other oils intended primarily for use against the San José scale. They mix readily with cold water and are immediately available for use. While quickly prepared, easily applied, and generally effective, they cost considerably more than lime-sulfur. They are, however, less corrosive to the pumps and more agreeable to use, and they have a decided value in special cases as for destroying the eggs of the fruit-tree leaf-roller. They should be diluted with not more than 15 parts of water, and should be used only on dormant trees when there is no danger of freezing.

Commercial concentrated lime-sulfur washes

Commercial concentrated lime-sulfur solutions are now widely used by fruit growers in combating certain insect pests and fungous diseases. Careful and extensive experiments have shown that these mixtures, when thoroughly applied, will give very satisfactory results in controlling San José scale, blister mite, and apple scab. For the control

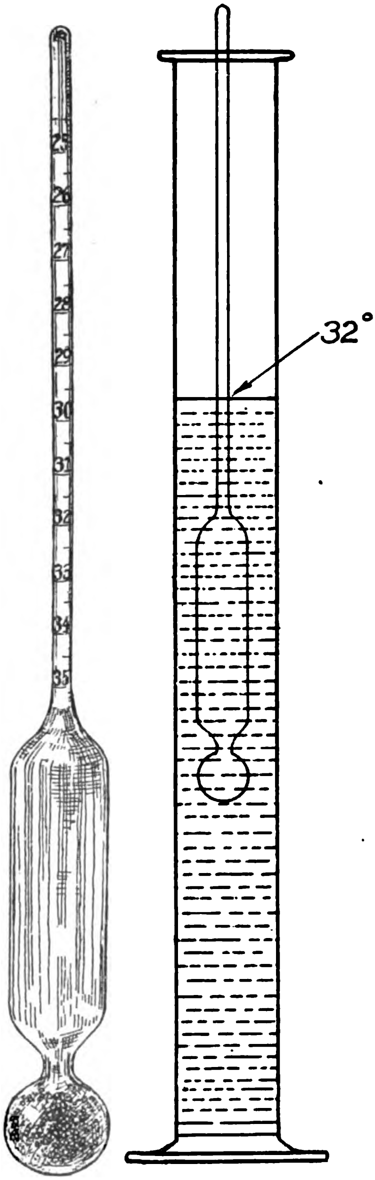


FIG. 232.—*Hydrometer used for testing concentrated lime-sulfur solutions*

of the two insect pests the material is applied to the infested trees only in the dormant period, and for apple scab it is applied as a summer spray in a much more diluted condition.

In order to use one of these mixtures intelligently and effectively it becomes necessary to know its strength, or, in other words, its degree of concentration. This is best found by using an instrument known as a Baumé hydrometer. An accurate hydrometer may be bought through a local druggist. The instrument should be designed for determining densities between 25° and 35° Baumé. In testing a lime-sulfur solution, some of the clear reddish liquid is poured into any deep receptacle, deeper than the hydrometer is long, and when the receptacle is full the instrument is dropped gently into the solution and left until the solution comes to rest. The degree of concentration, which is the one just at the surface of the liquid, is then read on the hydrometer. When the degree of concentration of the solution is known, the proper dilution may be obtained by referring to the following table, computed from data given in Bulletin 329 of the New York State Agricultural Experiment Station at Geneva:

Concentrate testing (degrees Baumé)	Dilution for San José scale and blister mite	Dilution for peach leaf curl (trees dormant)	Dilution for apple (summer spray)	Dilution for pear and cherry (summer spray)
35	1 to 8¾	1 to 16½	1 to 43½	1 to 56
34	1 to 8½	1 to 16	1 to 42½	1 to 54
33	1 to 8	1 to 15½	1 to 41	1 to 52
32	1 to 7½	1 to 15	1 to 40	1 to 50
31	1 to 7¼	1 to 14½	1 to 39	1 to 48
30	1 to 6¾	1 to 14	1 to 37½	1 to 46
29	1 to 6½	1 to 13½	1 to 36	1 to 44
28	1 to 6	1 to 13	1 to 35	1 to 42
27	1 to 5¾	1 to 12½	1 to 33½	1 to 40½
26	1 to 5½	1 to 12	1 to 32½	1 to 38½
25	1 to 5	1 to 11	1 to 31	1 to 37

Arsenate of lead may be added to the diluted concentrate at the rate of from 2 to 3 pounds to 50 gallons. Paris green, arsenite of lime, or arsenite of soda, should not be used with lime-sulfur.

Homemade concentrated lime-sulfur solution

Fairly satisfactory concentrated solutions may be made at home, if the work is done carefully and thoroughly. Homemade solutions will vary considerably and must all be tested in order to determine the dilutions. They will probably contain more or less sediment. In order to make them with as little sediment as possible, lime at least 90 per cent pure should be used and the mixture should be constantly stirred while cooking. The Geneva formula calls for 36 pounds of pure lump lime or 38 pounds of 95-per-cent lump lime or 40 pounds of 90-per-cent lime, with 80 pounds of flowers of sulfur or sulfur flour and 50 gallons of water. The following directions for making the solution are condensed from Bulletin 330 of the State Experiment Station at Geneva, by P. J. Parrott and W. J. Schoene: Heat about 10 gallons of water and use it to slake the lime. As slaking commences add the sulfur and stir vigorously in order to break up lumps. When the lime is all slaked add enough water to make about 60 gallons if the boiling is done in an open kettle. Boil vigorously for one hour. If the mixture is to be stored, strain it into a barrel and cork tightly so

as to prevent evaporation. Store where there is no danger of freezing. When ready to use, test the concentrate with a Baumé hydrometer and dilute according to the foregoing table.

Fumigation with hydrocyanic acid gas

Hydrocyanic acid gas is a deadly poison and the greatest care is required in its use. From 98- to 100-per-cent-pure potassium cyanide only should be used, and a good grade of commercial sulfuric acid. The chemicals are always combined in the following proportion: potassium cyanide 1 ounce, sulfuric acid 1 fluid ounce, water 3 fluid ounces. Only an earthen dish should be used. *The water should be poured in first,* and the sulfuric acid added to it. The required amount of cyanide is put into a thin paper bag, and when all is ready it is dropped into the liquid and the room must be left immediately. For mills and dwellings, 1 ounce of cyanide should be used for every 100 cubic feet of space. The doors and windows should be made as tight as possible by placing strips of wet paper over the cracks. Silverware and food should be removed, and if brass and nickle work cannot be removed it should be covered with vaseline or with cloths. The proper amount of the acid and water for every room is then placed in 2-gallon jars; two or more of these are used in large rooms or halls. The potassium cyanide is weighed out in paper bags, which are placed near the jars. When all is ready, the cyanide is dropped into the jars, beginning on the top floors since the fumes are lighter than air. In large buildings it is frequently necessary to suspend the bags of cyanide over the jars by cords running through screw eyes and all leading to a place near the door. By cutting all the cords at once the cyanide will be lowered into the jars and the operator may escape without injury. The fumigation should continue all night, all outside doors being locked and danger signs being placed on the house.

Fumigation of greenhouses

No general formula can be given for fumigating the different kinds of plants grown in greenhouses, as the species and varieties differ greatly in their ability to withstand the effects of the gas. Ferns and roses are very susceptible to injury, and fumigation, if attempted at all, should be performed with great caution. Fumigation will not kill insect eggs, and therefore must be repeated when the new brood appears. Fumigating should be done only at night when there is no wind. The house should be as dry as possible, and the temperature as near 60° as is practicable.

FUNGICIDES

The most important fungicides are as follows: bordeaux mixture, concentrated lime-sulfur, self-boiled lime-sulfur, ammoniacal copper carbonate, potassium sulfide, copper sulfate, sulfur, corrosive sublimate, and formaldehyde.

Bordeaux mixture

Bordeaux mixture is made by mixing a dilute solution of copper sulfate (blue vitriol) with a dilute milk of lime. The mixture may be made of different strengths by using different amounts of the copper sulfate and lime to a given amount of water. A mixture made of 3 pounds of copper sulfate and 3 pounds of lime to 50 gallons of water is indicated by the formula 3–3–50; one made of 4 pounds of copper sulfate and 4 pounds of lime to 50 gallons of water, by 4–4–50; one made of 5 pounds of copper sulfate and 5 pounds of lime to 50 gallons of water, by 5–5–50; and so on. In order to make bordeaux mixture of any strength, the procedure should be as follows:

Stock solution of copper sulfate.— A stock solution of copper sulfate may be made in a barrel, using 50 pounds of copper sulfate dissolved in 50 gallons of water. A gallon of the solution thus contains 1 pound of copper sulfate. In case large quantities

of stock solution are needed, two pounds of copper sulfate may be dissolved to one gallon of water. If the crystals, placed in a gunny sack, are suspended so as to be just beneath the surface of the water, they will dissolve in the course of three or four hours.

Stock lime.— A stock mixture of lime may be made by placing a bushel of good stone lime in a barrel, and slaking by the gradual addition of water. Care must be taken not to " drown " the lime. When all has become pulverized by the slaking, water is added to make a paste, after which enough more water is added to make 50 gallons. This should not be allowed to dry out. Hydrated lime (which is already slaked) may be used in place of stone lime, but air-slaked lime should never be used.

Making the mixture.— The sprayer is filled three-fourths full of water. If a 5-5-50 solution is desired, 5 gallons of copper sulfate stock solution is added to this water for every 50 gallons of mixture to be made. The solution requires stirring until it is well diluted, after which 5 gallons of the stock mixture of milk of lime is added to each 50 gallons of mixture. The lime water should be run through a strainer in order to prevent the large particles of lime from getting into the sprayer tank. While the milk of lime is being added to the dilute copper sulfate solution in the sprayer tank, the material in the tank should be stirred constantly. The sky-blue bordeaux mixture will result. Enough water to make the required amount of mixture is then added.

Testing the mixture.— The mixture should next be tested with a few drops of a solution of potassium ferrocyanide. This is made by dissolving crystals of potassium ferrocyanide in soft water. Five cents' worth of crystals dissolved in a pint of water will provide enough of the solution to last throughout the season. Should a brown-colored precipitate result when a few drops of this solution are added to the bordeaux mixture, it would indicate that more lime milk is needed to neutralize the copper sulfate solution. When sufficient lime is added, no brown precipitate will be formed by the potassium ferrocyanide solution. Bordeaux mixture not properly neutralized will burn the foliage of plants when applied to it. It is unnecessary to measure the milk of lime in making the bordeaux mixture if the mixture is tested from time to time with ferrocyanide solution while adding the lime. The test will indicate when sufficient lime is present.

Bordeaux injury (Fig. 233)

Some plants are injured by bordeaux of ordinary strength, even when it is properly made. Others, as the apple, are sometimes injured by a weak bordeaux under certain weather conditions. The leaves of most varieties of stone fruits, especially peaches and Japanese plums, are almost sure to be injured by bordeaux except in very weak mixtures. The injury to these plants consists usually of small holes in the leaves, very similar in appearance to the shot-hole effect of certain fungi. The injury on apple occurs on both the leaves and the fruit. On the leaves it consists of definite brown spots very much like certain leaf spots due to fungi. On the fruit the injury takes the form of russeting. It may even cause large cracks to appear. Some varieties of apple suffer more than others. Wet weather during the spraying season appears to be one of the chief factors in the production of bordeaux injury on apples. It has also been shown that " the more copper sulfate, the greater the injury." This injury may be avoided by using lime-sulfur instead of bordeaux.

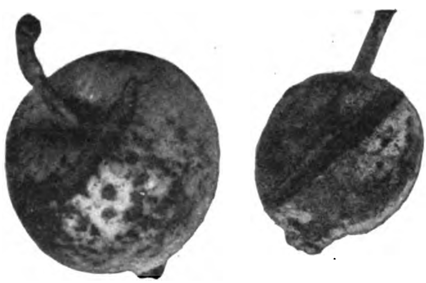


FIG. 233.—*Bordeaux injury on apples*

Concentrated lime-sulfur—See under *Insecticides*, page 464.

Self-boiled lime-sulfur

Self-boiled lime-sulfur is not a boiled solution, as might be inferred from the name. It is prepared by placing in a barrel 8 pounds of the best stone lime, to which is added a small quantity of cold water in order to start it slaking. Eight pounds of sulfur worked through a sieve to break up the lumps is then added slowly to the slaking lime, which is kept from burning by the addition of cold water; care must be taken, however, not to add so much water that the lime will be drowned. The slaking mixture must be stirred constantly. Just as soon as the slaking is completed (which should be in from five to fifteen minutes), the barrel is filled with cold water (50 gallons). The mixture is strained into the sprayer tank through a sieve of 20 meshes to the inch. It must be agitated constantly while being applied, as it settles rapidly. When properly made, this is merely a fine mechanical mixture of lime and sulfur produced by the heat and the bubbling action of slaking, and should have but little sulfur in solution. This mixture is especially adapted for the spraying of peaches and plums in foliage, as it causes no injury. Arsenate of lead may be added.

Ammoniacal copper carbonate

Ammoniacal copper carbonate is composed of 5 ounces of copper carbonate, 3 pints of ammonia, and 50 gallons of water. The ammonia is diluted in 7 or 8 parts of water, and a paste is made of the copper carbonate with a little water. The paste is added to the diluted ammonia and stirred until dissolved. Enough water to make 50 gallons is added. This mixture loses strength on standing, and should be made as required. It is used in place of bordeaux when one wishes to avoid the coloring of maturing fruits or ornamental plants. It is probably not so effective as bordeaux.

Potassium sulfide

Three ounces of potassium sulfide (liver of sulfur) is added to 10 gallons of water. As this mixture loses strength on standing, it should be made just before using. It is particularly valuable for the powdery mildew of many plants, especially of gooseberry, and for carnation rust, rose mildew, and the like.

Copper sulfate

One pound of copper sulfate is dissolved in from 15 to 25 gallons of water. It is then ready for use. One pound in twenty gallons of water has been found effective against peach leaf curl. This mixture should never be applied to the foliage, but must be used before the buds break. A much weaker solution has been recommended for trees in leaf, but it is rarely used.

Sulfur

Flowers of sulfur or extra finely ground sulfur flour possesses considerable value as a fungicide. The sulfur may be dusted over the plants, especially when they are wet. It is most effective in hot, dry weather. In rose houses, it is mixed with half its bulk of lime and made into a paste with water. This is painted on the steam pipes. The fumes destroy mildew on the roses. Mixed with lime, it has proved effective in the control of onion smut when drilled into the rows with the seed. Mixed with powdered arsenate of lead at the rate of 90 pounds of sulfur to 10 pounds of lead, it has proved effective in the control of biting insects and of apple scab.

Corrosive sublimate solution

One ounce of corrosive sublimate is mixed with 7½ gallons of water. It is an effective solution for treating seed potatoes, which should be soaked for one and one-half hours. One antiseptic tablet dissolved in a pint of water and stored in glass makes a solution suitable for disinfection of wounds. After cutting out fire blight or

canker, the wound may be swabbed thoroughly with this solution. The solution should be used in wooden or glass vessels, as it reacts with metal and thereby loses strength. It is very poisonous. It is injurious to tools, and should be applied to the wounds, not to the tools.

Formaldehyde solution

Commercially formaldehyde solution contains about 40 per cent of the gas formaldehyde. One pint in 30 gallons of water will prevent potato scab if the tubers are soaked for two hours and planted in clean soil; or 1 pint in 45 gallons of water will prevent oat smut and stinking smut of wheat. The oat seed should be spread on the floor, sprinkled with the solution until it is wet, heaped up, and covered with blankets for from two to four hours.

Sticker, or adhesive

An efficient sticker may be made by mixing 2 pounds of resin, 1 pound of sal soda crystals, and 1 gallon of water. This is boiled until of a clear brown color — from one to one and one-half hours. It should be cooked in an iron kettle in the open. It is useful for onions, cabbage, and other plants that are hard to wet. This is the proper amount to be added to each 50 gallons of bordeaux for these plants; for other plants, this amount should be added to every 100 gallons of bordeaux. This mixture will prevent the bordeaux from being washed off by the heaviest rains.

Hot water

The smuts of certain cereals may be controlled by the use of hot water in treating the seed. The following so-called *modified Jensen method* is recommended in Bulletin 152 of the United States Bureau of Plant Industry, for treatment of seed for loose smuts of wheat and barley. This applies only to treating small quantities of seed for a seed plat from which clean seed for the general crop may be obtained.

"The clean seed should be soaked for from five to seven hours in water at ordinary room temperature, 17° to 22° C. (63° to 72° F.). It should be placed in small, loose sacks or wire baskets containing not more than one-half peck each and drained for a short time. It is of the greatest importance that the seed be treated in small lots in order that all of the grain may be quickly and uniformly brought to the desired temperature. Two tubs or vats of water should be provided. In one tub (No. 2) the exact temperature required should be maintained. The other tub (No. 1) is used for bringing the grain to the temperature of the treatment, so as not to lower the temperature in tub No. 2. Galvanized iron tubs of 20 to 40 gallons capacity and kerosene or gasoline double-burner stoves are sufficient for the treatment. The drained sacks or baskets of seed should be plunged into tub No. 1 for a minute, then transferred to tub No. 2, and kept agitated while immersed at temperatures and for the periods specified below, the temperatures mentioned being maintained as nearly as possible:

For barley, 15 minutes at 52° C. (125.6° F.).
For wheat, 10 minutes at 54° C. (129.2° F.).

"In treating barley, if the temperature should rise above 52° C. (125.6° F.) the time of immersion must be reduced to ten minutes at 53° C. (127.4° F.) or five minutes at 54° C. (129.2° F.). Above 54° C. (129.2° F.) there is no safe margin. If the temperature falls slightly below 52° C. (125.6° F.) the time of treatment should be increased in proportion. A temperature lower than 51° C. (123.8° F.) will not be effective. In treating wheat, if the temperature should rise above 54° C. (129.2° F.) or fall below 52° C. (125.6° F.), the time for immersion must be diminished or increased accordingly. Under no circumstances should a temperature of more than 55° C. (131° F.) be allowed. Temperatures below 51° C. (123.8° F.) are ineffective.

"Seed treated as indicated may be planted as soon as it is sufficiently dry to run freely through the drills. . . . . . . In many cases the grain germinates as well or better when rested after treatment than if sown immediately. . . . . .

"A good thermometer should be used for all treatments. . . . .

"Several weeks before sowing, the seed should be tested for germination."

SPRAYING SCHEDULE FOR APPLES

Dormant spray. — *As the buds begin to show green*

Lime-sulfur (32° Baumé) diluted 1 to 8, for San José scale, oyster-shell scale, and blister mite. If aphids are present this application should be delayed until just as the buds are bursting; at that time the young lice are clustering on the opening buds.

"Black leaf 40" tobacco extract should be added, ¾ pint to 100 gallons of lime-sulfur solution.

Summer sprays

(A) *As the buds begin to show pink*

Lime-sulfur (32° Baumé) diluted 1 to 40, for apple scab; from 4 to 6 pounds of arsenate of lead should be added to 100 gallons of lime-sulfur, for bud moth and case-bearers.

(B) *As the last of the petals are falling*

Lime-sulfur (32° Baumé) diluted 1 to 40, for apple scab; from 4 to 6 pounds of arsenate of lead should be added to 100 gallons of lime-sulfur, for codling moth. *This is the most important spray for the control of the codling moth.*

(C) *Three weeks after the petals fall*

Lime-sulfur (32° Baumé) diluted 1 to 40, for apple scab; from 4 to 6 pounds of arsenate of lead should be added to 100 gallons of lime-sulfur, for codling moth.

(D) *The last week in July*

Lime-sulfur (32° Baumé) diluted 1-40, for apple scab; from 4 to 6 pounds of arsenate of lead should be added to 100 gallons of lime-sulfur for the second brood of codling moth.

SPRAYING SCHEDULE FOR PEACHES

Dormant spray. —*Before the leaf buds swell*

Lime-sulfur (32° Baumé) diluted 1-8, for San José scale and peach leaf curl. If San José scale is not to be combated, lime-sulfur (32° Baumé) diluted 1 to 15, or bordeaux 4-4-50, should be used.

Summer sprays

(A) *About the time when the calyxes, or shucks, are dropping from the young fruit*

(a) Self-boiled lime-sulfur 8-8-50, with arsenate of lead, 2 pounds to 50 gallons, for scab.

As this is rather early for scab and rot, the self-boiled lime-sulfur may be omitted, using merely

(b) Arsenate of lead, 2 pounds to 50 gallons of water, for curculio.

If the self-boiled lime-sulfur is omitted, milk of lime, made by slaking from 2 to 3 pounds of good stone lime, should be added to each 50 gallons of water. This will tend to counteract any caustic action of the arsenate of lead.

(B) *Two or three weeks later, or about one month after the petals fall*

(a) Self-boiled lime-sulfur 8-8-50, for scab and brown rot.

(b) Two pounds of arsenate of lead added to the preceding, for curculio.

(C) *About one month before the fruit ripens*

Self-boiled lime-sulfur 8-8-50, for brown rot. Arsenate of lead must not be added.

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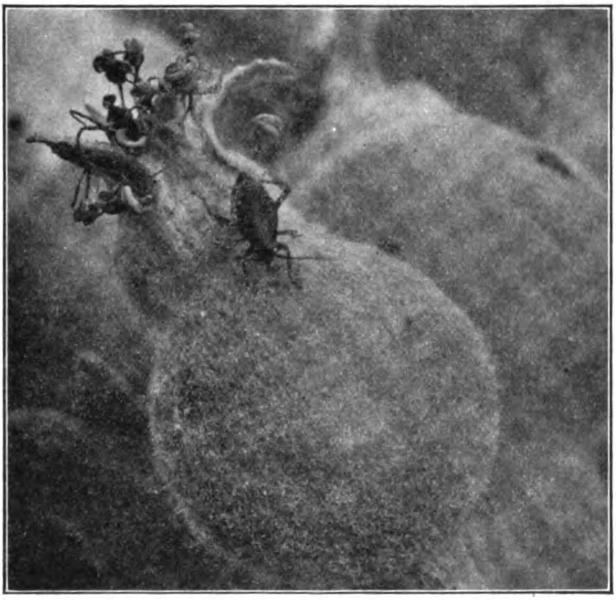
CORNELL UNIVERSITY

AGRICULTURAL EXPERIMENT STATION OF

THE COLLEGE OF AGRICULTURE

Department of Entomology

THE APPLE REDBUGS



Nymph of apple redbug feeding on a young apple

BY C. R. CROSBY

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THE APPLE REDBUGS

Heterocordylus malinus Reuter and *Lygidea mendax* Reuter[1]
Order, *Hemiptera* Family, *Capsidæ*

C. R. Crosby

Two apple pests are considered in this bulletin. In the preparation of the bulletin free use has been made of the notes and photographs accumulated by the late Professor M. V. Slingerland, whose observations on the apple redbugs began in the spring of 1896. Although these insects had been observed on apples at Ithaca from time to time for a number of years, they did not seem to be of sufficient importance to warrant particular study until the spring of 1908, when a serious outbreak was reported in an orchard near Syracuse, New York. Professor Slingerland visited the orchard, and in the notes taken at that time he wrote: "The injury being done in this orchard is sufficient to warrant a careful study of the life history of this insect, with remedial treatment." In the winter of 1909 he outlined to the writer his plans for carrying out this work, and it is greatly to be regretted that his untimely death prevented its completion.

Considering the importance of the subject and the desirability of placing Professor Slingerland's observations in permanent form, the writer undertook to carry on the work. Cooperative experiments in means of control have been conducted during the last two years at Ithaca, Syracuse, Brockport, and Waterloo, New York. In the spring of 1910 both species of the insect were reared in the Insectary at Cornell University, and careful drawings of each stage have been made by Miss A. C. Stryke.

Knotty apples are caused by a number of insects. The plum curculio deforms the fruit with its characteristic feeding and egg-laying punctures; plant lice, or aphids, when abundant cause stunted and misshapen fruit. The injurious work of these insects has long been known and is familiar to every fruit grower. In 1908 Judson N. Knapp, of Syracuse, called Professor Slingerland's attention to his orchard, in which the fruit was badly deformed but in such a way that the injury could not be attributed to either of these well-known pests. The injury in this orchard was very severe, nearly the entire crop of certain varieties being rendered unmarketable.

The culprit was soon identified by Professor Slingerland as one of the leaf bugs, which in its immature stages is a brilliant tomato red. More

[1] Described by O. M. Reuter, *Acta Soc. Sci. Fennicæ*, 36: 47, 71. 1909.

recently it has been learned that this insect is aided in its destructive work by another closely related, but entirely distinct, species, also of a bright red color. The results of observations and experiments with these two sucking bugs are here presented, in order that fruit growers may become familiar with them and be prepared to fight them whenever they appear in serious numbers.

COMMON NAMES

These insects are known among fruit growers by the highly appropriate name *redbugs*. As names are needed to distinguish the two species, it is proposed to call the darker form (*Heterocordylus malinus*) the *apple redbug* and the lighter form (*Lygidea mendax*) the *false apple redbug*.

FIRST INDICATION OF THE PRESENCE OF REDBUGS

The eggs of the redbug hatch just before the blossoms open; those of the false redbug about a week later. Although the nymphs of both species are a brilliant red while young, they are hard to find because of their habit of hiding between the opening leaves. Some of the inner leaves remain curled lengthwise for several days, and the tube thus formed makes a snug retreat for the young bugs. The first indication of their presence is the minute reddish spots on the leaves caused by their feeding punctures (Fig. 87). They usually feed on the upper surface, and make a large number of punctures in a single leaf.

It is sometimes desirable to determine in advance of the spraying season whether or not an orchard is infested with redbugs. If twigs from bearing branches are brought into the house any time after the first of March and placed in water to force out the buds, the redbug eggs will hatch soon after the leaves appear. Their presence is indicated by the reddish dots on the leaves caused by their feeding punctures.

LIFE HISTORY

The eggs

The eggs of both species are laid in late June or early July. They are inserted for their full length into the bark on the smaller branches of the trees, two-years-old wood being preferred. The eggs are very difficult to find and it was not possible to make as many observations on them as was desirable.

All eggs definitely known to belong to the redbug (*H. malinus*) were found inserted in a slit in the bark at the base of the fruit spurs (Fig. 88). On hatching, the young nymph leaves the embryonic covering which pro-

trudes from the egg cavity as shown in Figure 89. As far as the writer has observed, the normal number of eggs for each cavity is four. The egg is 1.6 millimeters long by .4 millimeter wide, rather strongly curved, slightly compressed, and dull whitish in color. The embryo develops in the lower enlarged part, its head being at some distance from the tip of the egg. The woody tissue of the bark, especially the outer part, adheres so closely to the egg that it is impossible to remove it completely even if it is hardened in alcohol.

The eggs of the false redbug (*L. mendax*) are usually inserted in pairs in the lenticels of smooth two-years-old wood. In Figure 90 is shown a part of a small branch bearing two lenticels, each of which contains two eggs. One of the lenticels is shown in Figure 91, greatly enlarged. The eggs are not always placed in lenticels, as is shown in Figure 92. They do not lie parallel to one another, but diverge at a wide angle in order to avoid the solid wood, since they are longer than the thickness of the bark. A section of a twig with an egg in position is shown in Figure 93. The egg is 1.6 millimeters long by .4 millimeter wide.

The eggs of the redbug begin to hatch soon after the leaves of the fruit buds open, and the hatching is practically completed by the time the blossoms open. The eggs of the false redbug hatch about a week later. The spring of 1910 was abnormally early, and the first nymphs of the redbug were found on April 8 at Ithaca and Syracuse. B. H. Henion reported finding nymphs on April 9 near Brockport.

The nymphs

Both species pass through five immature stages and develop wings at the fifth molt. Under natural conditions the time required for the nymphs to reach maturity varies considerably with the weather. In the Cornell Insectary, which is heated by steam, the redbug required about thirty-five days and the false redbug about thirty-seven days. Under these conditions each stage lasted about one week. A much longer time is required in the orchard.

The young nymphs of the two species are very similar. Those of the false redbug may be distinguished by their brighter red color, by the absence of dusky markings on the thorax, and by the fine, short, black hairs covering the body. The nymphs of this species retain their bright color until they are full-grown; those of the redbug become nearly black on the thorax after the third molt. In the redbug nymphs the beak is dusky; in the other species it is nearly colorless, with a black tip. The immature stages of the redbug are shown in Figures 81 to 85, and the second, third, fourth, and fifth stages of the false redbug are shown in Figure 86.

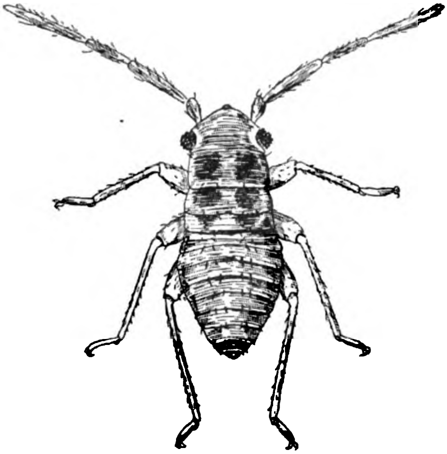


FIG. 81.—*Apple-redbug nymph. Stage I. Length,* 1.2 *millimeters.* (*See Figs.* 82, 83, 84, 85)

Technical description of the nymphs

The following descriptions are all taken from living specimens:

H. malinus.—Stage I. Length of insect, 1.2 millimeters. General color a light tomato red. Each segment of the thorax has a large, transverse, medially interrupted, dusky area, the one on the metathorax being smaller than the others and obliquely truncate laterally. Head dusky, with two oblique light lines which on the vertex meet the median line of the thorax. Legs, antennæ, and beak slightly dusky, the antennæ yellowish red at the joints. As growth progresses the first and second abdominal segments shorten and the constrictions become deeper. (Fig. 81.)

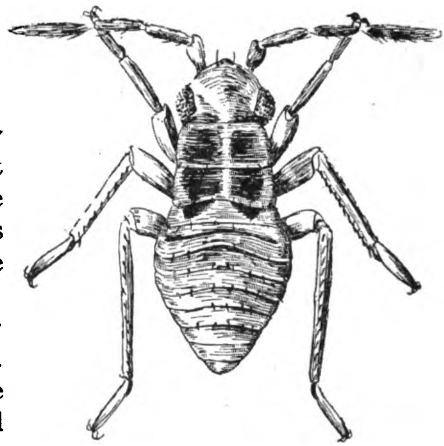


FIG. 82.—*Stage II. Length,* 1.7 *millimeters*

Stage II. Length of insect, 1.7 millimeters. Head dusky reddish. Thorax with the median line and the posterior margin of the prothorax and the mesothorax red, the remainder dusky over a red ground color. Abdomen tomato red, with irregular lighter markings toward the sides; the first segment with a broad, transverse, dusky spot, the second with a smaller spot, the next six segments each with a very small spot, and the ninth with a large dusky area. Legs and antennæ dusky over a red ground color. Beak dusky. Under parts tomato red except for a small dark area just above the base of each leg. (Fig. 82.)

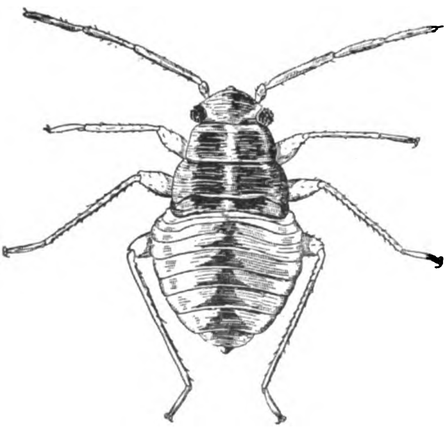


FIG. 83.—*Stage III. Length,* 2.2 *millimeters*

Stage III. Length of insect, 2.2 millimeters. Head and thorax dull reddish; small white area below and behind the eye. The wing pads begin to show on the mesothorax. Abdomen with a median row of dull reddish spots, those on the first; second, and ninth segments the largest; general color of abdomen bright red, variegated with white laterally, the white markings more pronounced anteriorly; narrow posterior margin of first and second segments white. Antennæ dull reddish, lighter at the joints. Legs dull reddish, dusky distally. Beak dusky. (Fig 83.)

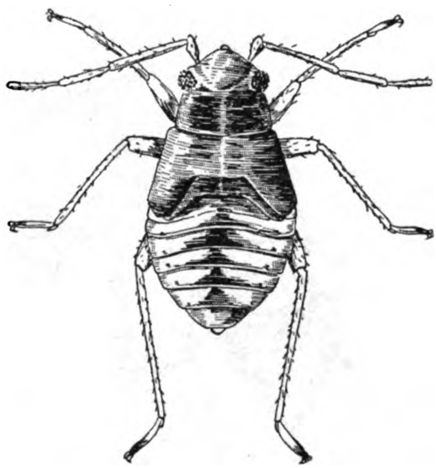


FIG. 84.—*Stage IV. Length,* 2.5 *millimeters*

Stage IV. Length of insect, 2.5 millimeters. Head and thorax as in preceding stage, except that the red is darker and the median line is whitish; narrow posterior margin of prothorax bright red. The wing pads extend to the third segment. Abdominal markings as in preceding stage, except that the median reddish brown areas are larger, and all but the anterior margin of the ninth segment is of this color. Legs, antennæ, and beak darker than in the last stage. (Fig. 84.)

Stage V. Length of insect, 4.3 millimeters. Head and thorax dull black over a red ground color; median line of thorax whitish. First and second abdominal segments nearly black over reddish, posterior margin of each white; third to eighth segments light red, variegated with lighter markings; median longitudinal row of large, transverse, reddish black spots; ninth and tenth segments reddish black, except for the red anterior margin. Legs and antennæ nearly black, with a reddish ground color. Abdomen beneath lighter red, with a submarginal row of small black spots; ninth ventral segment nearly covered by a large black spot; a smaller spot on the eighth segment. (Figs. 85 and 94.)

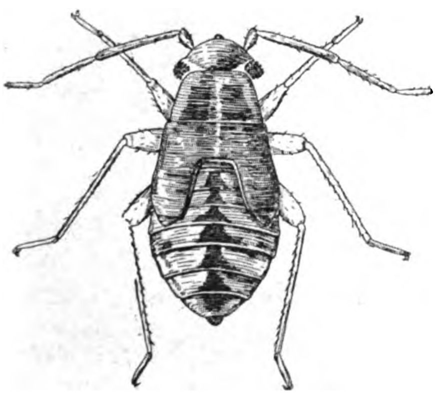
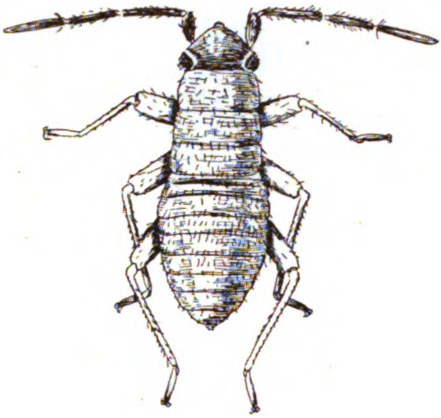
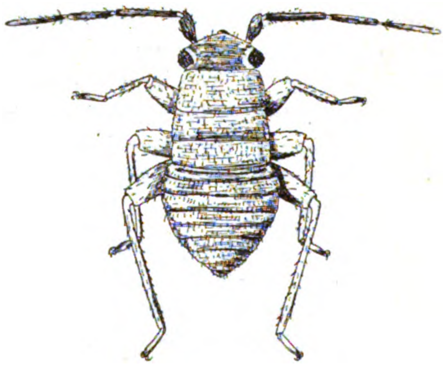


FIG. 85.—*Stage V. Length,* 4.3 *millimeters*

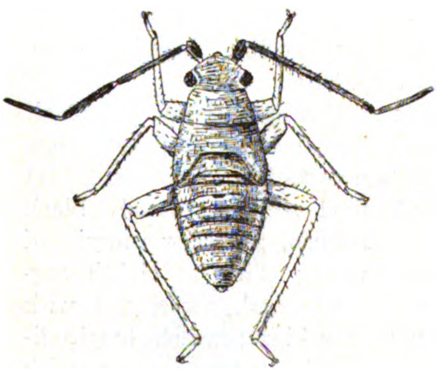
L. mendax.—Stage I. Length of insect, 1.5 millimeters. General color tomato red. A distinct whitish ring around eye. Thorax slightly dusky over a red ground color. Legs dusky. Antennæ brownish. Beak colorless, with the tip black. Whole dorsal surface clothed with short, stiff, black hairs.



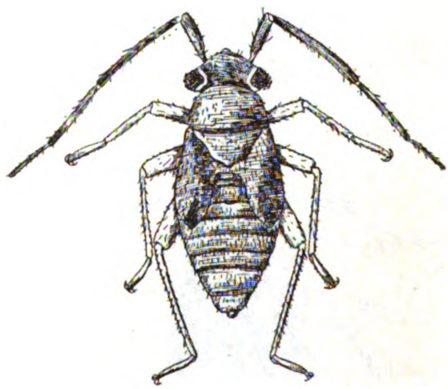
Stage II. Length, 2.5 *millimeters*



Stage III. Length, 2.7 *millimeters*



Stage IV. Length, 3.25 *millimeters*



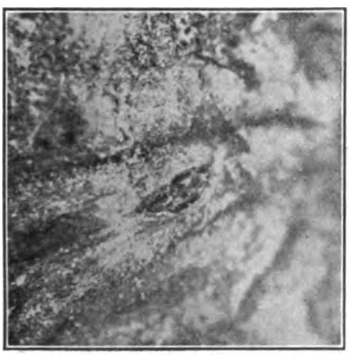
Stage V. Length, 4 *millimeters*

FIG. 86.—*Immature stages of the false apple redbug*

Stage II. Length of insect, 2.5 millimeters. Very similar to first stage. Antennæ dusky brown, last segment lighter except at base. Tylus dark.

Stage III. Length of insect, 2.7 millimeters. The wing pads just begin to show on the mesothorax. Coxæ tomato red; remainder of legs and beak translucent, slightly dusky; posterior tibiæ brownish; legs covered with stiff, black hairs. Tylus dark brown.

FIG. 87.—*Reddish dots caused by punctures of the false apple redbug*



PHOTOGRAPH BY V. I. SAFRO

FIG. 88.—*Eggs of apple redbug at base of fruit spur*

FIG. 89.—*Embryonic covering protruding from the egg cavity after the hatching of the apple redbug*

FIG. 90.—*Eggs of false apple redbug in two-years-old apple twig*

FIG. 91.—*Lenticel of apple twig, in which are inserted two eggs of the false apple redbug. Greatly enlarged*

FIG. 92.—*Two eggs of the false apple redbug not inserted in a lenticel*

FIG. 93.—*Section of twig showing egg of false apple redbug in position*

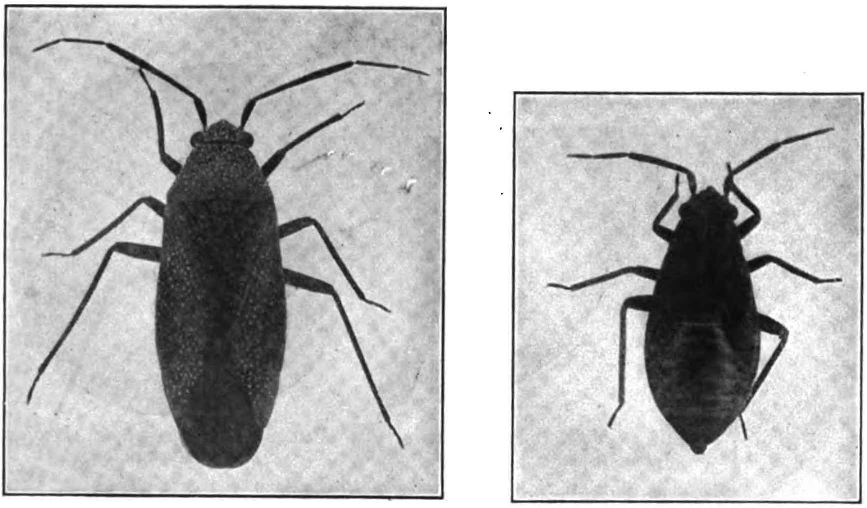


Fig. 94.—*Apple redbug. Adult and fifth-stage nymph*

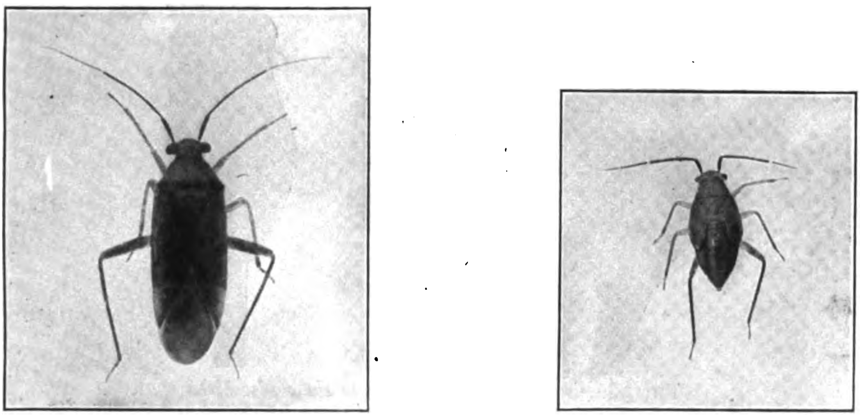


Fig. 95.—*False apple redbug. Adult and fifth-stage nymph*

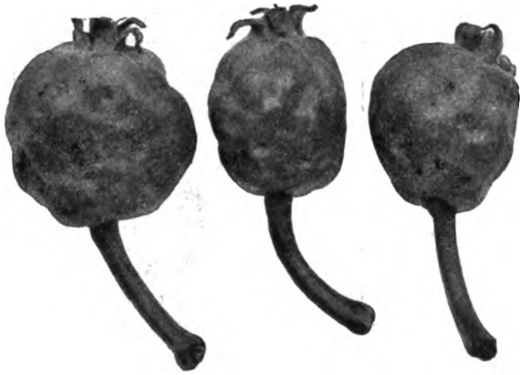


FIG 96.—*Small apples deformed by redbug punctures*

FIG. 97.—*Mature apple, showing injury by redbugs*

FIG. 98.—*Small apples cut open to show discolored areas around the punctures*

FIG. 99.— *Small apples punctured by redbugs, showing drops of gum*

FIG. 100.—*Leaves showing the results of redbug injury earlier in the season*

FIG. 101.—*Condition of blossom buds when redbug nymphs first appear*

Stage IV. Length of insect, 3.25 millimeters. Very similar to preceding stage in color. The wing pads extend nearly to the posterior margin of the second abdominal segment.

Stage V. Length of insect, 4 millimeters. Wing pads extend to fifth abdominal segment. General color bright tomato red. Tip of wing pads and line along scutellum dusky. Legs dusky, darker toward the tip. Antennæ dusky, nearly black; last segment brownish at base. Tylus jet black. Last two abdominal segments with a broad, median dusky mark on the dorsum. Whole body covered with short, fine, black hairs. (Figs. 86 and 95.)

The adults

The adult redbug (*H. malinus*) is about one-quarter inch long (Fig. 94). The general color varies from red to nearly black. Usually the thorax is black in front and red behind. The wings are red, usually black along the inner edge and with a pointed ovate black spot near the outer margin. The scutellum, legs, and antennæ are black. The eyes are dark red. The entire dorsal surface is sparsely covered with conspicuous white, flattened, scale-like hairs.

The adult false redbug (*L. mendax*) is of about the same size as the preceding species, but the general color is lighter and the white, scale-like hairs are lacking (Fig. 95). The head and the prothorax are orange-red, the latter with a narrow, black, posterior border. The scutellum is orange-red in front, and blackish posteriorly. The wings have a band of orange-red along the outer edge; the inner part is dusky. The amount of red on the wings varies greatly in different individuals; in some the wings are almost entirely reddish, in others they are dusky. The eyes are dark red. The antennæ are black. The legs are dusky yellow, darker toward the tip.

HABITS OF THE NYMPHS

Very soon after hatching the nymphs move to the young leaves, on which they feed until they are full-grown in case fruit is not available. In the Insectary both species have been reared to the adult stage exclusively on foliage. Usually, if fruit is present the nymphs attack it as soon as it has set, and sting it to death with their feeding punctures. As they grow older they become more active, and when disturbed they retreat to the twig, where they adroitly dodge to the opposite side like a squirrel. If frightened they frequently drop from the branch, but they rarely fall to the ground, usually alighting on another branch. They have a curious way of getting a new hold on a branch or a leaf. The posterior end of the alimentary canal can be extruded, and is covered with a viscid secre-

tion. As soon as the insect strikes an object in falling, the sticky organ adheres to it until a foothold can be obtained. When confined in a glass bottle young nymphs become attached to the glass so firmly in this way that they cannot escape, and so perish.

HABITS OF THE ADULTS

Even in a badly infested orchard in which the crop has been practically ruined, it is very difficult to capture the adults. They dodge to the opposite side of the branch at the slightest alarm, and then suddenly take flight.

The laying of eggs has not been observed, but it probably takes place during June and July. In the case of the false redbug it may be deferred until September.

INJURY TO THE FRUIT

While the most conspicuous work of the redbug is found on the leaves, this damage is very slight. Those leaves that are badly punctured early in the season become curled, and in some cases drop off (Fig. 100). A little later the bugs attack the tender leaves at the tips of the growing branches, and frequently stop growth by their punctures.

The principal injury, however, is caused by the punctures in the young fruit. The apples are then very small, and the four sharp bristles of the bug's beak penetrate quite to the center. The picture on the cover page, which is from a photograph taken by Professor Slingerland, shows a nymph feeding on a young apple. The plant tissue around each puncture becomes discolored and hardens (Fig. 98). Many of the punctured apples fall to the ground, others dry up on the trees; the remainder mature, but they are badly deformed and are rendered unmarketable (Figs. 96 and 97). Sometimes a drop of gum oozes from each puncture (Fig. 99).

When first reported in the Syracuse orchard, the injury was principally confined to Rhode Island Greenings; recently, however, redbugs have attacked Pumpkin Sweets (Pound Sweets), Ben Davis, and Northern Spies. In 1908 the injury in the Syracuse orchard amounted to twenty-five per cent of the crop. In the same year the entire crop of Rhode Island Greenings in the Frear orchard near Ithaca was destroyed. Nearly all the young apples of this variety were punctured, and dropped early in the season; other varieties in the same orchard were only slightly injured. D. B. Weaver, of Waterloo, New York, states that during past years the injury in his orchard has amounted to about one thousand dollars a year. B. H. Henion, of Brockport, estimates his yearly loss at from three to five hundred dollars. In 1909 the presence of aphids in great numbers made any estimate of the extent of redbug injury almost impossible.

DISTRIBUTION

Both species are generally distributed throughout the apple-growing section of New York. Reuter reports the redbug from Glen Ellyn, Illinois, and from Colden, New York. Both species have been reared in the Insectary from apple twigs sent from Brockport, Syracuse, La Fayette, Batavia, Waterloo, West Palmyra, and Albany. Dr. Uhler, in a letter to Professor Slingerland, states that the insect was studied by Dr. Asa Fitch at Salem, New York, but that his observations were never published. The false redbug is recorded by Reuter from Hamburg, Gowanda, and Colden, New York. Injuries to apples caused by redbugs have been reported also from New Jersey, Michigan, and Ontario (Canada). Both species appear to be native to America, and probably originally fed on the wild thorn.

A species closely related to the redbug occurs in Japan, where it is known as the Ringokuragama (*Heterocordylus flavipes* Matsuma). An interesting account of its habits is given by I. Nitobe in the Insect World, vol. x, no. 1, January, 1906. The following is a free translation of a part of this paper, which is in Japanese: "The eggs hatch right after the bursting of the buds. At first the nymphs puncture the young leaves and stems and feed on the sap. During the season of blossoming they gather on the flowers, and later on the young and immature fruits. When the skin of the fruit becomes hard they return to the leaves, which they injure considerably. If two or three insects gather on a leaf the development of the leaf is disturbed; in case of four or five insects the development of the leaf is entirely stopped. The parts of the leaf that are bitten never recover, and remain curled. The portion of the fruit punctured remains undeveloped, and thus the fruit is deformed."

From the fact that this Japanese insect belongs to the same genus as the American redbug, and from their close similarity in habits, it was at first thought that they were identical. However, T. Shiraki, Government Entomologist of Formosa, who examined our specimens, pronounces them distinct.

FOOD PLANTS

The writer has found redbugs feeding abundantly on wild thorn, and Dr. E. P. Van Duzee states in a letter that he found the adults abundant on thorn trees, where they appeared to be feeding on aphids. Mr. Nitobe states that in Japan *H. flavipes* occurs on the pear as well as on the apple.

METHODS OF CONTROL

The redbugs are sucking insects. They do not feed by chewing parts of the plant, but suck the sap through the tube formed by the four slender

bristles of the beak. For this reason it is impossible to kill them by poisoning their food with an arsenical spray. Such insects can be controlled only by sprays that kill by contact.

In these experiments no attempts were made to kill the adults, since they are relatively few in number and at the time of their appearance the trees are in full foliage, making it practically impossible to hit them.

The eggs are so inserted in the bark that the embryo develops at some distance from the surface, where it is impossible to destroy the insects by any application to the bark. Knowing that just at the time of hatching the nymphs are very delicate and tender, an attempt was made to kill them by coating the bark thoroughly with the lime-sulfur wash just before the time of hatching. Two trees of Rhode Island Greenings in the midst of a badly infested orchard were chosen for this purpose. They were sprayed on April 24 with commercial lime-sulfur, diluted 1-8. The experiment was unsuccessful, as the nymphs appeared on these trees as abundantly as on those not treated.

Professor Slingerland (Proceedings of the New York State Fruit Growers' Association, 1909, page 123) suggested that redbug nymphs might be controlled with a strong soap or kerosene-emulsion spray applied just before the blossoms open. In 1909 experiments along this line were conducted in three orchards, but owing to the destructive outbreak of the apple aphis and to other causes no definite conclusions could be drawn from them. It was learned, however, that the nymphs are very hard to kill with either whale-oil soap or kerosene emulsion, and that commercial whale-oil soap is very likely to burn young apple foliage.

In 1909 a few small experiments were made against the young nymphs, using commercial lime-sulfur diluted 1-30. No insects were killed unless the liquid was applied so freely as to practically drown them.

In 1910 these experiments were repeated on a larger scale, using whale-oil soap and nicotine preparations.

Whale-oil soap

Whale-oil soap is really a fish-oil soap, but as the older name is retained by the manufacturers there is less confusion if it is called by that name. In order to determine the amount of burning caused by whale-oil soap when applied to very young apple foliage, tests were made with three brands of the commercial product. In each case there was more or less injury, but with only one brand was it severe.

Dr. L. L. Van Slyke (New York [Geneva] Agr. Exp. Sta. Bulletin 257, 1904) has shown that the burning of foliage by whale-oil soap is caused by the presence of an excess of free or uncombined alkali. The writer applied to several soap manufacturers for samples of whale-oil soap free

from uncombined alkali, but was unable to obtain any. One firm replied that whale-oil soap is a resultant by-product and therefore not uniform in strength, and that the amount of alkali must vary with the conditions met with in making. Another wrote, "Manufacturing the product commercially, it is impossible to eliminate the free alkali." This seemed strange in the light of Dr. Van Slyke's work in making whale-oil soap at home. In order to try it here, the writer bought the necessary material and made twenty pounds, following Dr. Van Slyke's directions. It was found to be a very easy and simple operation, and the soap was practically free from uncombined alkali and was considerably less expensive than that on the market. When tested on young apple foliage in comparison with the commercial brands, the homemade soap caused no burning whatever. These tests were made soon after the buds opened and just before the proper time to spray for the redbug nymphs. While this homemade soap was safe to use on the foliage, neither it nor any of the commercial brands were effective in killing the nymphs.

Nicotine preparations

Failing to get satisfactory results from the use of either kerosene emulsion or whale-oil soap, certain tobacco preparations were tried. In the preliminary experiments, "black leaf," "nico-fume," and "black leaf 40" were used, and these were found effective at the following strengths: "black leaf" diluted 1-65, "nico-fume" diluted 1-700, and "black leaf 40" diluted 1-816. In later experiments which were conducted on a larger scale, only "black leaf" and "black leaf 40" were used. Both proved effective at the strengths indicated above when once the nymphs were thoroughly wet with the spray. Following a suggestion of Professor C. P. Gillette (Journal of Economic Entomology, vol. iii, page 210), the writer found that the addition of about 2 pounds of soap to each 50 gallons of the liquid made it spread better, and that in a measure it lost its tendency to collect in small drops without wetting the insect.

D. B. Weaver, of Waterloo, New York, whose orchard was badly infested by redbugs, used "black leaf" at the rate of 1 gallon in 100 gallons of dilute lime-sulfur to which arsenate of lead had been added, and reports excellent results in the control of redbugs. This combination has since been tried on a large scale by many growers, and has been found thoroughly satisfactory.

How to spray for redbugs

The results of the writer's experiments show that the young nymphs may be killed by an application of "black leaf 40" tobacco extract diluted at the rate of 1 pint in 100 gallons of water. The efficiency

of this spray is increased by the addition of about 4 pounds of soap to each 100 gallons.

The majority of the eggs of the redbug hatch after the opening of the leaves of the fruit buds and before the blossoms open. The condition of the foliage at this time is shown in Figure 101. The first application of the spray should be made just before the blossoms open and while the nymphs are small, soft, and tender. The condition of the blossoms and the foliage at this time is shown in Figure 102. This is also the proper time for making the first application for apple scab. The foliage is not

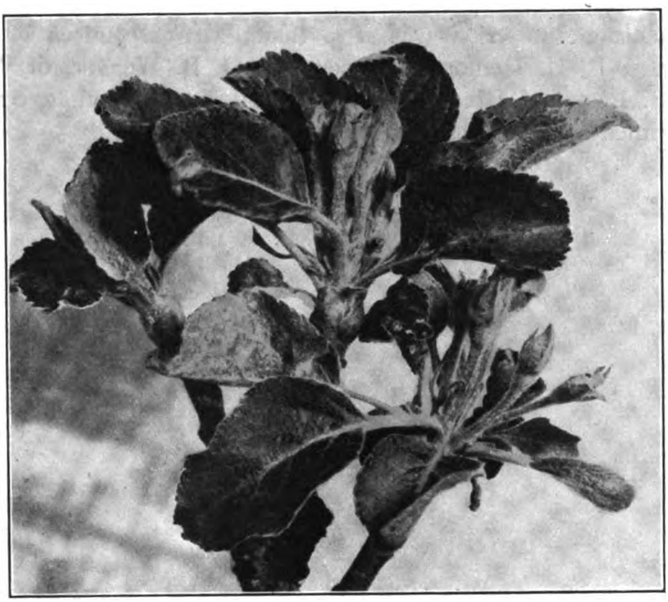


FIG. 102.—*Time for first application for redbugs*

so far developed as to give the bugs as much protection as is the case if the spraying is deferred until after blossoming. As the eggs of the false redbug and some of those of the redbug hatch during the time when the trees are in blossom, a second application may sometimes be necessary just after the blossoms fall. At this time the tobacco preparation may be added to the lime-sulfur and arsenate of lead as used for apple scab and for codling moth. If the insects are extremely abundant, however, it is necessary to use such large quantities of the liquid that the lime-sulfur may injure the foliage; in such cases a separate application should be made for redbugs, using the tobacco extract with water and soap.

In spraying for redbugs, the greatest thoroughness is necessary. It must be remembered that the spray kills by contact only, and that in order to get satisfactory results each insect must be hit with enough liquid to wet it thoroughly. A general spray directed at the whole side of the tree will leave many parts untouched. A good plan to follow is to spray the tree branch by branch, starting at the top and following each branch down toward the trunk. A fairly coarse nozzle should be used, with moderate pressure — that is, 100 to 120 pounds.

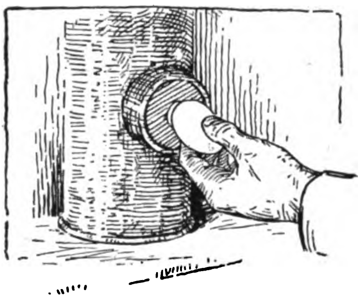
ACKNOWLEDGMENTS

In conclusion the writer wishes to thank Messrs. Judson N. Knapp, of Syracuse, B. H. Henion, of Brockport, D. B. Weaver, of Waterloo, and L. B. Frear, of Ithaca, for their kind cooperation in conducting the experiments located in their orchards.

NOVEMBER, 1914 BULLETIN 353

CORNELL UNIVERSITY
AGRICULTURAL EXPERIMENT STATION OF
THE COLLEGE OF AGRICULTURE
Department of Poultry Husbandry

THE INTERIOR QUALITY OF MARKET EGGS



By EARL W. BENJAMIN

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Experimenting Staff

The regular bulletins of the Station are sent free to persons residing in New York State who request them.

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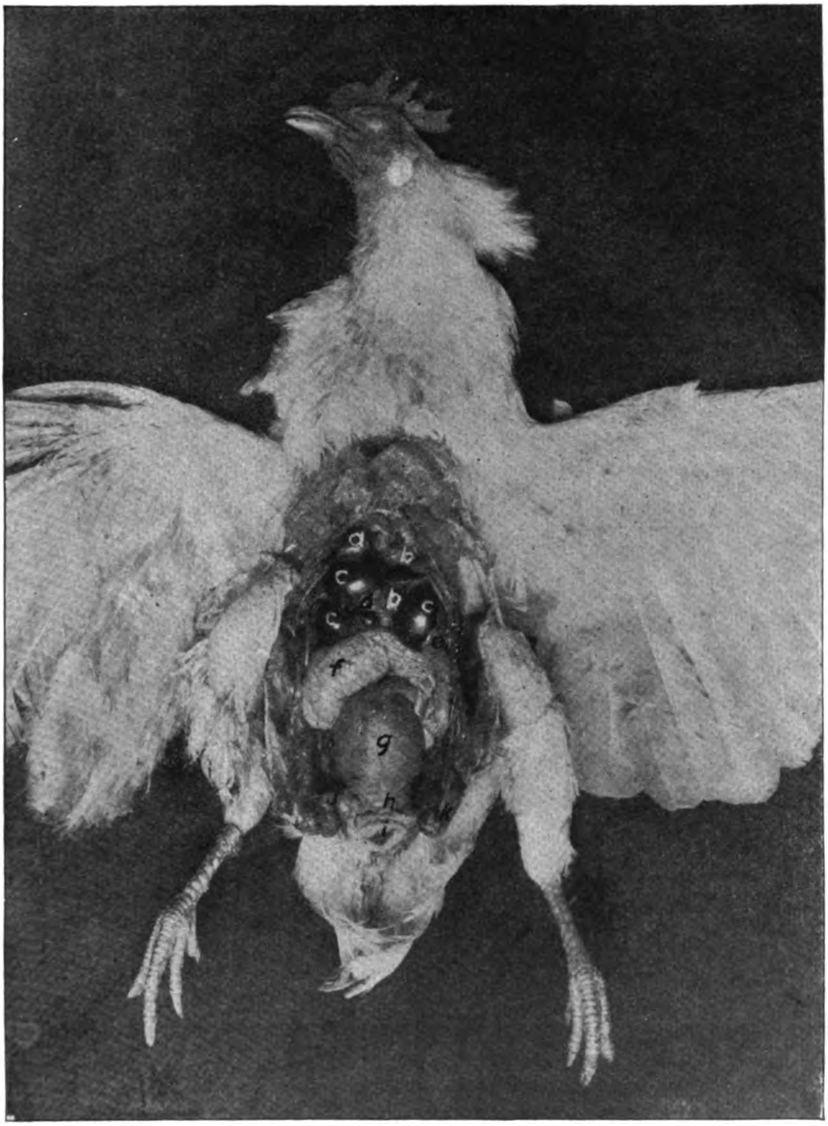


FIG. 1.— *Relative location of oviduct in body of fowl:* a, *heart;* b, *ovary tissue;* c, *undeveloped yolks;* d, *empty yolk sac;* e, *funnel opening into oviduct;* f, *albumen-secreting region of oviduct with yolk inside;* g, *uterus with completed egg inside;* h, *vagina;* i, *cloaca;* j, *end of large intestine;* k, *one side of pelvic arch*

THE INTERIOR QUALITY OF MARKET EGGS

EARL W. BENJAMIN

(*Received for publication June 1, 1914*)

It is very probable that comparatively few persons understand, as thoroughly as they wish, the processes and factors concerned in the production and handling of eggs for use as food. During the last few years it has become generally known that eggs are greatly affected by the conditions under which they are kept, as well as by the length of time they are kept. The reasons for this, the changes that occur, and the methods of detecting the interior quality of the eggs, should be more thoroughly understood by every one who is concerned with the production or consumption of eggs.

The purpose of this bulletin is to give to producers and consumers some information relative to the interior quality of eggs. To the former this is given so that they will be able to produce the quality that is demanded; to the latter, so that they will be able to buy more economically, and will know what properties to demand in market eggs. It is hoped that the bulletin may serve as a reference for purchasers and as a guide for producers and market men.[1]

THE PHYSIOLOGY OF EGG PRODUCTION

Each normal egg of the domestic fowl contains every essential for the maintenance of life and the development of a normal embryo during a period of twenty-one days. Every time a hen lays a fertile egg she reproduces herself. An egg must therefore be of complex structure, and a study of the nature of the different parts should lead to an understanding of how to handle eggs in order to keep them in the best possible condition.

The egg-producing organ of the domestic fowl, the oviduct (Figs. 1 and 2), is located in the rear part of the body cavity. It is in this organ that the egg structure shown in Figure 4 is completed. The yolk of the egg is the first part to develop; this process takes place in the ovary, which is located close to the backbone of the fowl. The ovary contains many hundreds of minute yolks (Fig. 2, *1*). If a normal fowl is killed while in laying condition, these yolks are found in all stages of development. Each yolk is enclosed in a sac, or follicle, through which it obtains its nourishment while developing.

[1] Shortly before the manuscript of this bulletin was completed, the writer received a copy of Bulletin 51 of the United States Department of Agriculture, entitled *A Study of Commercial Eggs in the Central West*. If readers of this publication wish to obtain further information relative to the bacteriological or chemical study of the various types of eggs discussed herein, they will do well to read this new bulletin, which has been prepared under the direction of Dr. M. E. Pennington.

When the yolk becomes mature (Fig. 2, *3*), the funnel-shaped opening of the oviduct (Fig. 2, *7*) rises and envelops the yolk sac. The yolk sac then splits along the suture line (Fig. 2, *4*) and allows the yolk inclosed in its vitelline membrane to escape and begin its passage through the oviduct (Fig. 2, *8*). If the egg is to be fertilized, the fertilization occurs just after the yolk has entered the oviduct and before any of the albumen is deposited. As soon as the yolk escapes from the yolk sac, the sac contracts and usually remains as unabsorbed tissue (Fig. 2, *5*). Some experimenters have found that the approximate number of eggs produced by a fowl can be roughly determined by counting the number of empty yolk sacs in the ovary.[2]

About forty per cent of the white, or albumen, of an egg is said to be laid on the yolk as it passes down through the upper half of the oviduct. The albumen deposited at this time probably represents the two dense inner layers of albumen and the chalazæ (Fig. 2, *10*).

After the yolk has passed this albumen-forming region, it passes into the isthmus, where the shell membranes are added with ten to twenty per cent more albumen. By this time the egg is beginning to assume its final size and shape, and it now passes into the uterus, where the remainder of the albumen, about forty per cent, is added, and the shell is formed (Fig. 2, *14*). The egg then passes through the vagina, where some of the shell pigment and the outer gelatinous coating of the shell are probably added. Then it is ready for expulsion from the body, through the cloaca.

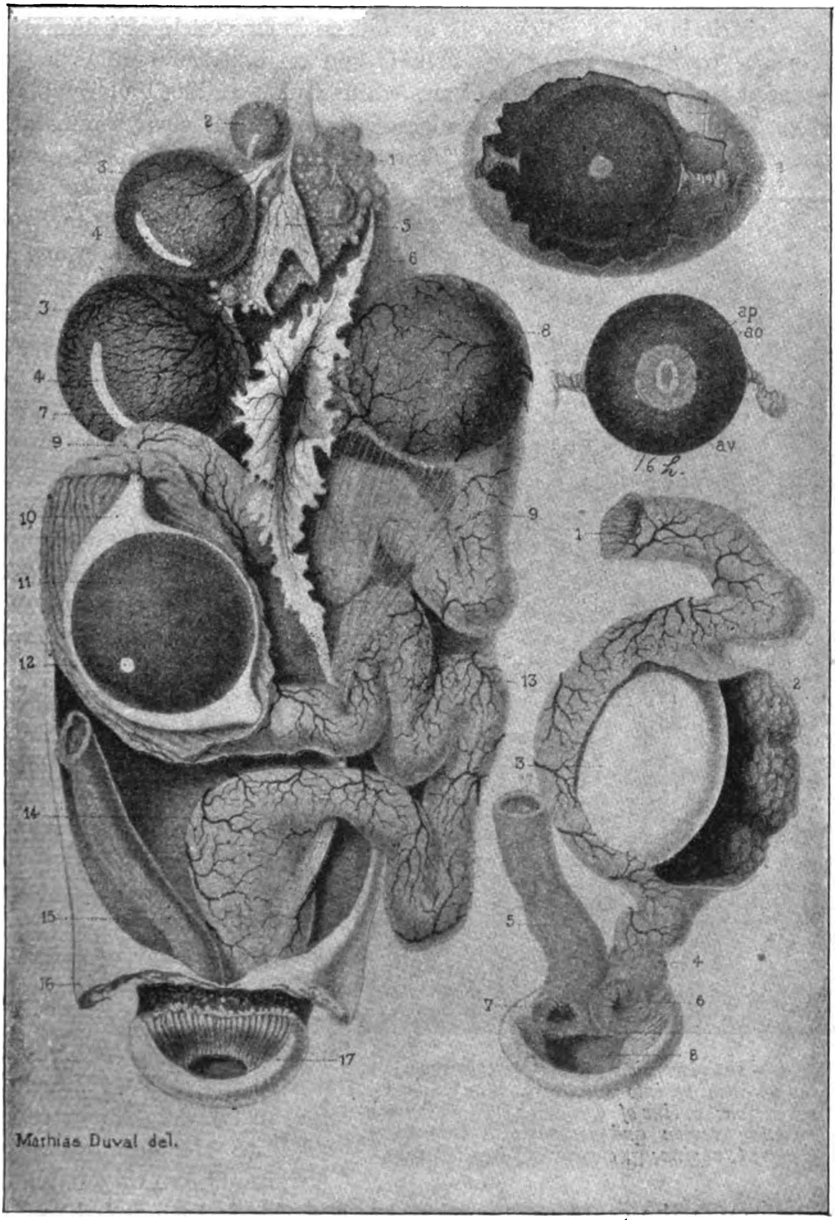
The various sets of glands on the oviduct wall may be noted in Figure. 3. These glands excrete their substance when irritated by the approach of the incompleted egg through the oviduct. Some observers have found that eggs expelled from the body prematurely were insufficiently colored, due probably to their rapid passage through the vagina.

The shape of the normal egg is probably determined by many factors, including the tension of the oviduct walls and the size of the egg. If we consider the shape of the egg to be the result of the physical forces in the oviduct walls, tending to push the egg forward, it is the natural assumption that these forces would tend to make the rear of the egg pointed. Nearly all authorities agree, however, that the egg is not always laid blunt end foremost. This would indicate that the foregoing theory of forces is at fault, or that the position of the egg often becomes reversed in the uterus.

THE STRUCTURE OF A NORMAL EGG

The structure resulting from the processes just described is shown in Figure 4. The yolk is gradually developed in the yolk sac by the addition

[2] Much work along this line has been done at the Maine Agricultural Experiment Station, by Dr. Raymond Pearl and his assistants.



FROM DUVAL'S ATLAS

FIG. 2.— *Oviduct of a laying hen:* 1, *ovary, with minute ovules;* 2–3, *yolk sacs;* 4, *suture line;* 5, *empty yolk sac;* 7, *funnel opening into oviduct;* 8, *yolk in oviduct;* 9, *albumen-secreting region;* 10, *albumen being secreted;* 11, *yolk passing through oviduct;* 12, *germinal disk;* 13, *isthmus;* 14, *uterus;* 15, *large intestine;* 17, *cloaca*

On the right-hand side of the figure are shown, from the top downward: complete egg; yolk of egg incubated for sixteen hours; completed egg in uterus—(1) *isthmus,* (2) *glands of uterus,* (3) *complete egg,* (4) *vagina,* (8) *cloaca*

of concentric layers of yellow yolk around an inner vesicle of white yolk. According to Lillie, the yellow yolk is laid on daily in regular layers, separated by very thin strata of the white yolk. As the yellow yolk is laid on, the germinal disk moves gradually outward, always remaining close to the vitelline membrane. This moving disk leaves a path behind it, filled with white yolk, across which no yellow yolk is deposited. Professor C. A. Rogers has found that about fourteen days are required for the full development of the yolk from its original minute size. The layers vary in thickness, as might be expected, probably owing to physical conditions of the bird, rate of laying, and the like. When the yolk is mature the germinal disk appears as a light-colored spot on the surface.

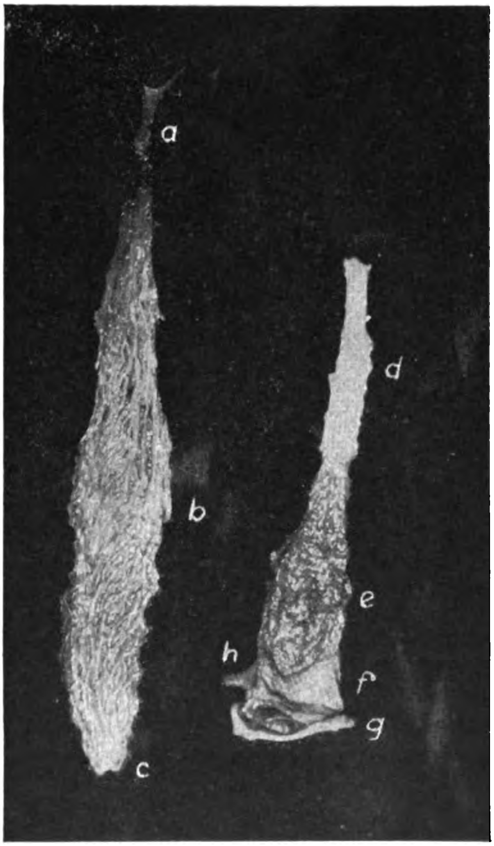


FIG. 3.— *Interior view of complete oviduct:* a, *funnel opening into oviduct;* b, *albumen-secreting region;* c, *line of division between albumen-secreting region and isthmus;* d, *isthmus;* e, *uterus;* f, *vagina;* g, *cloaca;* h, *large intestine*

The first albumen to be deposited on the yolk is the very thin, dense layer, close to the vitelline membrane and continuous with the chalazæ. The chalazæ are attached at opposite sides of the yolk, extending out into the albumen toward the ends of the egg. The size and position of the chalazæ vary in different eggs; they may be twisted up close to the vitelline membrane or extended out into the thin albumen. A white, fibrous thread usually runs through the center of the chalazæ, and this is surrounded by the dense, partially transparent albumen. In normal eggs the yolk is lighter than the albumen, and tends to rise and stick to the shell; in very stale eggs the yolk tends to sink. The chalazæ act as a drag in either case, preventing any rapid change in the position of the yolk. The

chalazæ allow the yolk to spin on the longitudinal axis of the egg; this allows the yolk to always swing around so that the germinal disk is on the upper side, which is essential in order that the germ may receive the maximum amount of heat from the sitting hen or the incubator.

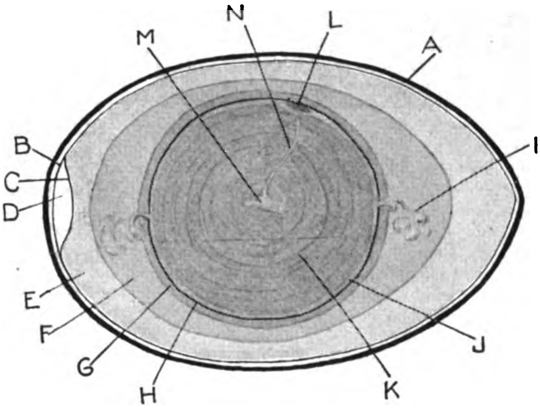


FIG. 4.— *Structure of an egg:* A, *shell;* B, *outer shell membrane;* C, *inner shell membrane;* D, *air cell;* E, *outer thin portion of albumen;* F, *middle jelly-like portion of albumen;* G, *inner dense portion of albumen;* H, *vitelline membrane;* I, *chalaza;* J, *thin film of white yolk inside of vitelline membrane;* K, *layers of yellow yolk separated by thin layers of white yolk;* L, *germinal disk;* M, *central part of yolk filled with white yolk;* N, *slender tube connecting center of yolk with region of germinal disk*

Next to the dense inner layer of albumen there is a thicker middle layer having somewhat less density. This layer varies in thickness and may be distinguished by its jelly-like appearance when the egg is opened into a dish. The third, or outer, layer of albumen, next to the shell membranes, is very watery and transparent. The inner, outer, and middle layers make up the albumen, or white, of the egg. Outside of the albumen are the inner and the outer shell membranes, which are added in the isthmus (Fig. 2). These consist of a network of organic fibers (Fig. 5). The inner membrane is of finer texture than the outer one, although the fibers in both are nearly transparent. The two membranes serve to protect the contents of the egg from outside sources of contamination.

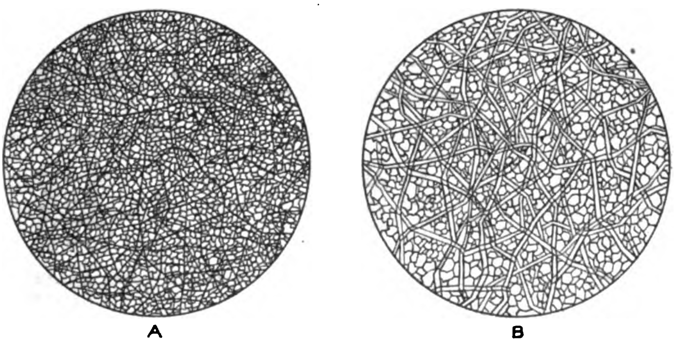


FIG. 5.— *Shell membranes of an egg (highly magnified).* A, *Inner shell membrane. Note the fine cellular structure. The cells are bound together by many intertwining fibers.* B, *Outer shell membrane. This is much coarser in structure than the inner membrane. The fibers are very transparent*

The shell (Fig. 6) is a calcareous deposit added to the outer shell membrane in the uterus. The shell seems to consist of three layers, as stated by Lillie.

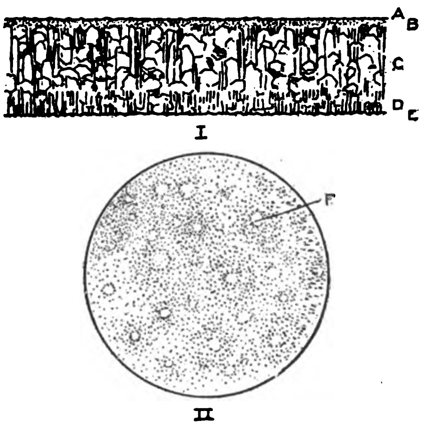


FIG. 6.— *Shell structure of an egg (highly magnified)*

I, *Cross section of eggshell:* A, *gelatinous coating over the shell;* B, *outer porous layer of shell;* C, *middle granular portion of shell;* D, *inner crystalline layer of shell;* E, *inner face of shell, shown in* II

II, *Inner face of eggshell.* F, *hexagonal section of crystal. This inner face shows the indefinite outlines of the crystalline structure of the inner layer of the shell*

When the egg is first laid, it is completely filled; but as soon as it cools, the contents contract and an air space is formed, usually between the two shell membranes and at the point where these easily divide. This air space usually forms at the large end of the egg, and is about one half inch in diameter in the normal egg.

A part of the characteristic pigment and all of the bloom, or gelatinous coating, of the egg, is secreted in the vagina. This outside pigment may be removed with sandpaper or any similar abrasive substance. The gelatinous coating is easily dissolved by water or acids.

The composition of hens' eggs is somewhat variable, but is approximately as given in Table 1:

TABLE 1.— COMPOSITION OF HENS' EGGS

	Yolk (percentage)	White of egg (percentage)	Whole egg (percentage)
Water	46 – 52	80 – 88	70 – 76
Fat	30 – 35	Traces	9 – 14
Protein	14 – 16	10 – 13	10 – 15
Shell and shell membranes	....	....	9 – 12

From Table 1 it is seen that the whole egg usually contains over ten per cent of fat. Nearly all of this fat is in the yolk, and obviously the fowl must have a surplus of fat before the yolks can begin to develop. The eggs of ducks, geese, turkeys, guinea fowls, and other birds vary to some extent from the analysis noted above, but the differences are slight.

The detailed analysis of hens' eggs which follows is taken from Simon's textbook of physiological chemistry:

Analysis of shell (9 – 11 per cent of whole egg)

	Percentage
Calcium carbonate	90.00
Magnesium carbonate	Small amount
Calcium and magnesium phosphate	Small amounts
Water	1.00

Analysis of albumen (60.5 per cent of whole egg)

	Percentage
Water	80.00 – 86.68
Solids	13.32 – 20.00
Albumins	11.50 – 12.27
Extractives	0.38 – 0.77
Glucose	0.10 – 0.50
Fats and soaps	Traces
Mineral salts	0.30 – 0.66
Lecithins and cholesterin	Traces

The mineral ash of the albumen has been found by Poleck and Weber to consist of:

	Percentage
Sodium (Na_2O)	23.56 – 32.93
Potassium (K_2O)	27.66 – 28.45
Calcium (CaO)	1.74 – 2.90
Magnesium (MgO)	1.60 – 3.17
Iron (Fe_2O_3)	0.44 – 0.55
Chlorine (Cl)	23.84 – 28.56
Phosphoric acid (P_2O_5)	3.16 – 4.83
Carbonic acid (CO_2)	9.67 – 11.60
Sulphuric acid (SO_3)	1.32 – 2.63
Silicic acid (SiO_2)	0.28 – 0.49
Fluorine (Fl)	Traces

Analysis of the yolk (29 per cent of whole egg)

According to Gautier we have the following:

	Percentage
Water	47.19 – 51.49
Solids	48.51 – 42.81
Fats (olein, palmitin, and stearin)	21.30 – 22.84
Vitellin and other albumins	15.63 – 15.76
Lecithins	8.43 – 10.72
Cholesterin	0.44 – 1.75
Cerebrin	0.30
Mineral salts	3.33 – 0.36
Coloring matter, Glucose	0.553

Poleck and Weber also give the following as the analysis of the mineral salts of the yolk:

	Percentage
Sodium (Na_2O)	5.12 – 6.57
Potassium (K_2O)	8.05 – 8.93
Calcium (CaO)	12.21 – 13.28
Magnesium (MgO)	2.07 – 2.11
Iron (Fe_2O_3)	1.19 – 1.45
Phosphoric acid, free (P_2O_5)	5.72
Phosphoric acid, combined	63.81 – 66.70
Silicic acid (SiO_2)	0.55 – 1.40
Chlorine	Traces

According to Simon, the shell is made up of an organic matrix of the nature of keratin. This matrix is largely impregnated with lime salts. The pigments of the shell are said

to be derived from the common pigment of blood. The shell membranes are also composed largely of keratin, with a small amount of mineral salts, principally calcium phosphate. The white of the egg is supposed to consist of compartments which are divided by thin membranes and which contain the liquid albumen. These membranes are continuous with the chalazæ and the shell membranes. The yolk consists largely of spherical cells, most of which are filled with fat.

METHODS OF STUDYING THE INTERIOR QUALITY OF EGGS

The interior quality of eggs may be judged in various ways. If the air cell is broken so that the inclosed air merely forms a loose air bubble in the albumen, the contents of the egg will pound slightly when the egg is held in the hand and shaken vigorously. This is a common test, and eggs that shake in this way are often said to be rotten; however, they may be only evaporated. If the air cell is large, the egg should be handled very carefully or the inner shell membrane will invariably be broken, thus liberating the air as a bubble.

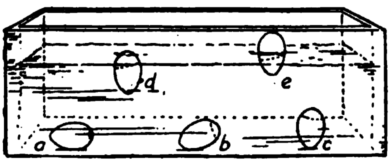


FIG. 7.— *The specific gravity test for stale eggs.* a, *A very fresh egg. Note the small air cell and the nearly horizontal position of the egg when immersed in water.* b, *Slight evaporation causes the egg to tip.* c, *Badly evaporated eggs stand on end.* d, *Very badly evaporated eggs float.* e, *An egg so badly dried that it is not fit for use*

A fairly accurate method of learning the amount of evaporation that eggs have undergone is by placing them in a dish of water (Fig. 7). A fresh egg will lie nearly flat on the bottom of the dish, but if the egg is slightly evaporated the end bearing the air cell will tip up slightly. This tendency to tip up increases with the degree of evaporation, until a very much evaporated egg will float on the surface of the water. This is a method that can be used by the consumer, but it does not show interior quality except so far as evaporation is concerned.

Mottled shells are often said to denote age in eggs, but this is true only to a limited extent. Black rots can sometimes be distinguished by a grayish appearance of the shell. If the shells are very smooth and glossy, this usually means that the eggs have been incubated for a considerable time. If the shells are stained, the eggs have been in contact with moisture and are usually inferior. If eggs are cleaned with acid, the shells appear very porous. Eggs cleaned in this way or by washing should usually be avoided if possible, for they will not keep well. Limed and water-glass eggs will usually bear deposits of the preservative in the pores of the shell, and they can thus be distinguished from fresh or cold-storage eggs.

The best commercial method of determining the interior quality of an egg is by the process of candling. This process consists in holding the

egg before a bright light and looking through it toward the light as shown in Figure 8. After a person has become accustomed to studying eggs in this manner, nearly every fault can be readily noted and understood. Other types of candling devices are shown in Figures 9 and 10. The chief requirement in a device for candling is that a bright light shall fall on the egg from the side opposite the observer's eye. An opening in a window curtain or a large funnel is often used for this purpose, thus utilizing daylight instead of some artificial light.

In order to candle an egg correctly it should be held below the eye, thus enabling the observer to readily note the size of the air cell. The writer prefers a position about twelve inches in front of and the same distance below the eye. The egg is usually candled with the end containing the air cell held upward; this is usually at the large end of the egg. As the egg is placed before the light it should be given a quick twist, the quicker the better, in order to start the contents whirling. This motion will throw any meat spots and the like toward the shell, where they may be better observed. It is

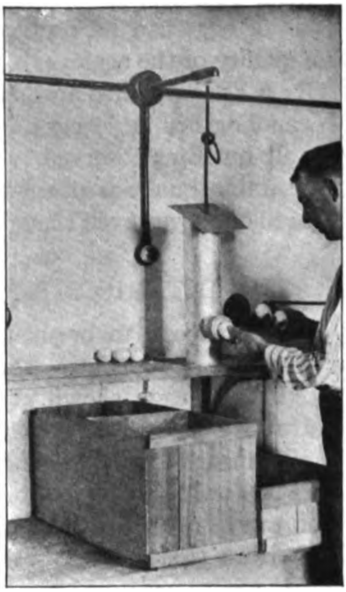


FIG. 8.—*Egg candler at work. This shows a desirable arrangement for a candling room*

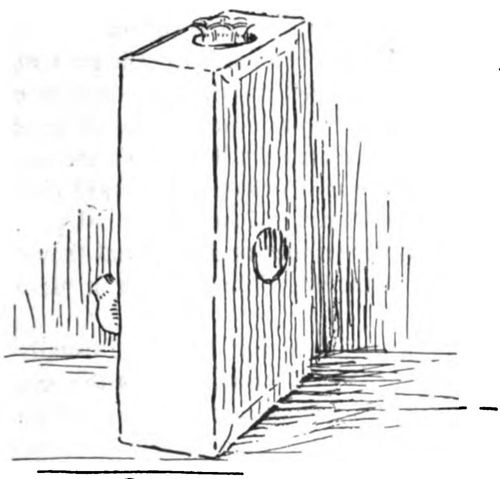


FIG. 9.—*A good candling apparatus may be made by arranging an ordinary oil lamp inside of a pasteboard box*

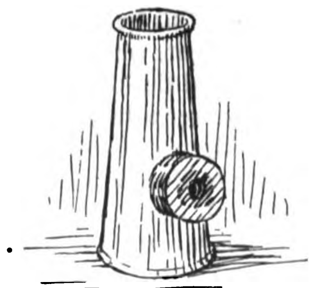


FIG. 10.—*A cheap type of candling apparatus is usually furnished with incubators. This type may be placed on an ordinary oil lamp in place of the regular chimney*

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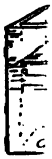

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PLATE I.— CANDLING APPEARANCE OF MARKET EGGS

1. *Oviduct lines on shell. Note spiral lines of darker pigment*

2. *A fresh white egg. Note the small air cell, the indistinct yolk, the pink albumen, and the chalaza in the upper left-hand part*

3. *A fresh brown egg. Note the small air cell, the dark contents, and the very indistinct yolk*

4. *A light float. Note the heated yolk and the enlarged air cell*

5. *A heavy float. Note that the yolk is very dark and low, the air cell is very large and loose, and the entire egg appears heated*

6. *A blind check. Note the fine indistinct lines of breakage, invisible except by candling*

7. *A check. Note that the shell is broken, but there is no leaking of contents. The air cell is enlarged*

8. *A meat spot. Note the distinct dark spot floating in the albumen, and the chalaza above and at the left of the meat spot*

PLATE II.—OPENED APPEARANCE OF MARKET EGGS

25. *A fresh egg. Note the round, firm yolk, the colorless, dense albumen, and the hard, twisted chalaza*

26. *A light float. Note the heated and somewhat flattened yolk, the tinted and slightly watery albumen, and the weak vitelline membrane*

27. *A heavy float. The yolk is darkened by heat and very much flattened, the vitelline membrane is very weak, and the albumen is colored and very watery*

28. *A meat spot. This is similar in appearance to a piec of liver. The meat spot may be easily removed*

almost impossible to candle eggs accurately without giving them this single quick twist. Two eggs are usually held in each hand by commercial candlers; some candlers prefer more. Two to four thirty-dozen cases of eggs can be candled in an hour, the speed varying according to the quality of the eggs.

By a little practice and study, the housewife can spend a few minutes in candling her table eggs and can know then approximately the causes for all qualities observed. There are so many causes by which various undesirable qualities of eggs may be produced, that it is often desirable to candle all eggs even though their quality is apparently above suspicion.

THE INTERIOR QUALITY OF A NORMAL FRESH EGG

As a standard to be used for comparison with all other eggs, the appearance of a strictly fresh egg (Plate 1, sects. 2 and 3)[3] should be noted. The eggs shown in this illustration were only five hours old and were kept under favorable conditions. The term "fresh," however, should mean a definite quality rather than a definite age, and will be used in the former sense throughout this bulletin.

In candling eggs the twisted appearance of the shell pigment will often be noticed (Plate 1, sect. 1). This appearance of the shell is apparently due to slight variations in the density of the pigment, which are probably formed as the egg passes through the vagina. Eggs from some hens display these lines much more plainly than do those from others.

The appearance of an egg before a light is greatly affected by the amount of pigment in the shell and the intensity of the light used. The difference due to the shell pigment is shown in Plate 1, sections 2 and 3. All the eggs shown in this bulletin were candled with a twenty-candle-power tungsten electric light, which is relatively white. A carbon electric light will give a slight red tint to an egg. An oil flame will give still more of a red tint. A gas burner with mantle will give eggs an appearance similar to that shown in the illustrations in this bulletin, while a gas fishtail burner has an effect similar to that of an oil flame.

A fresh egg has a very small air cell, so small that the light usually does not penetrate it, and it appears darker than the remainder of the egg. Except for the spots in the shell, the egg appears perfectly homogeneous. The yolk appears as a very dim shadow floating across the line of vision after the egg has been twisted before the candle. As the yolk moves around, there is usually an indistinct dark spot with an accompanying

[3] These illustrations of market eggs were made from actual specimens of the various grades. In each case the egg painted was selected as typical of a large lot. All eggs had white shells, except that used for Plate 1, section 3. The work was well in progress before the writer was aware that Doctor Pennington was contemplating work of a similar nature. Within a few weeks a color chart showing a few of the principal grades of eggs has been received from the Missouri Agricultural Experiment Station.

Plate I.— Candling appearance of market eggs

1. *Oviduct lines on shell. Note spiral lines of darker pigment*

2. *A fresh white egg. Note the small air cell, the indistinct yolk, the pink albumen, and the chalaza in the upper left-hand part*

3. *A fresh brown egg. Note the small air cell, the dark contents, and the very indistinct yolk*

4. *A light float. Note the heated yolk and the enlarged air cell*

5. *A heavy float. Note that the yolk is very dark and low, the air cell is very large and loose, and the entire egg appears heated*

6. *A blind check. Note the fine indistinct lines of breakage, invisible except by candling*

7. *A check. Note that the shell is broken, but there is no leaking of contents. The air cell is enlarged*

8. *A meat spot. Note the distinct dark spot floating in the albumen, and the chalaza above and at the left of the meat spot*

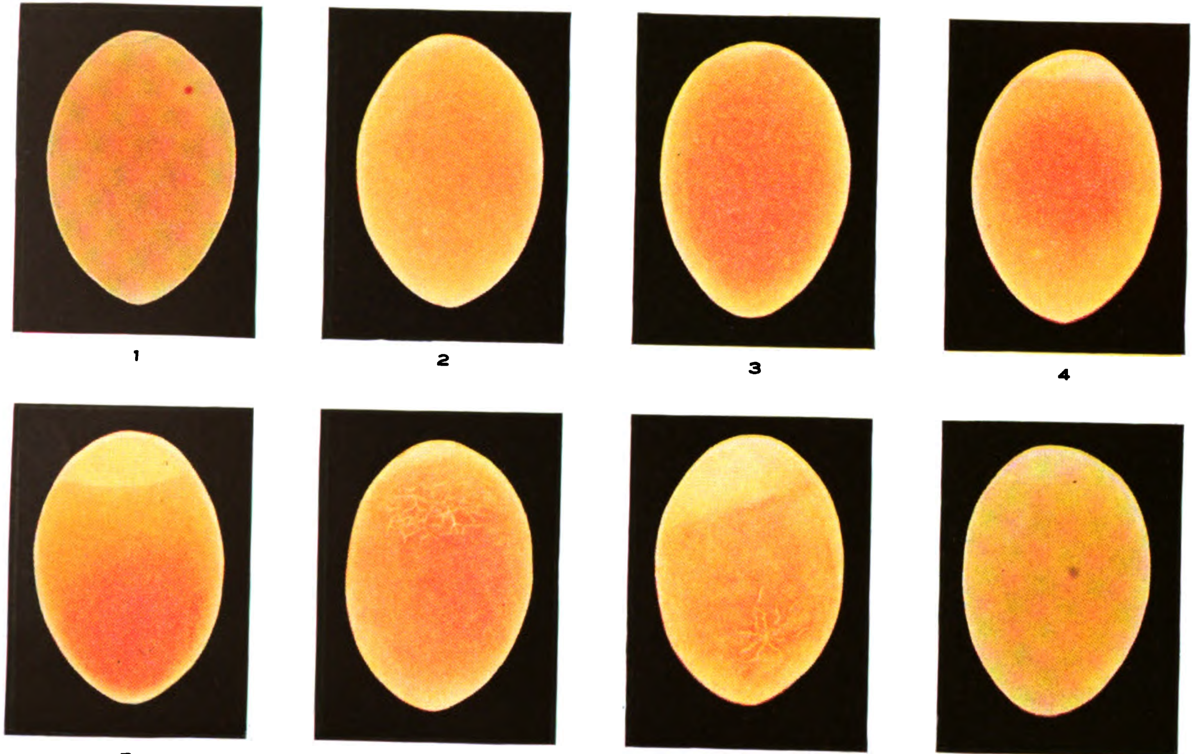
Plate II. —Opened appearance of market eggs

25. *A fresh egg. Note the round, firm yolk, the colorless, dense albumen, and the hard, twisted chalazæ*

26. *A light float. Note the heated and somewhat flattened yolk, the tinted and slightly watery albumen, and the weak vitelline membrane*

27. *A heavy float. The yolk is darkened by heat and very much flattened, the vitelline membrane is very weak, and the albumen is colored and very watery*

28. *A meat spot. This is similar in appearance to a piec of liver. The meat spot may be easily removed*



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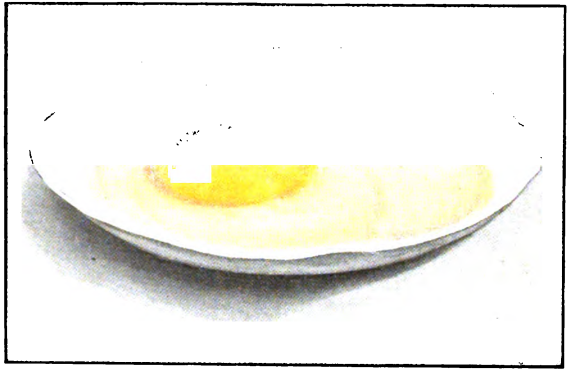

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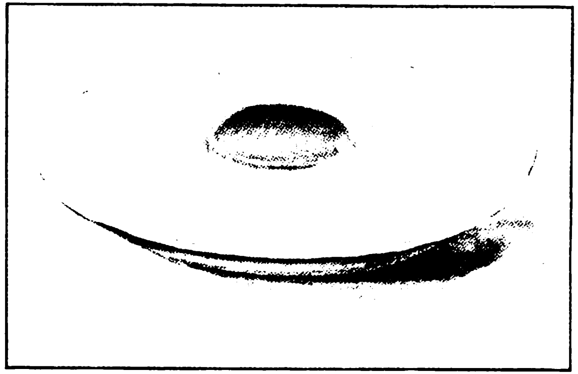

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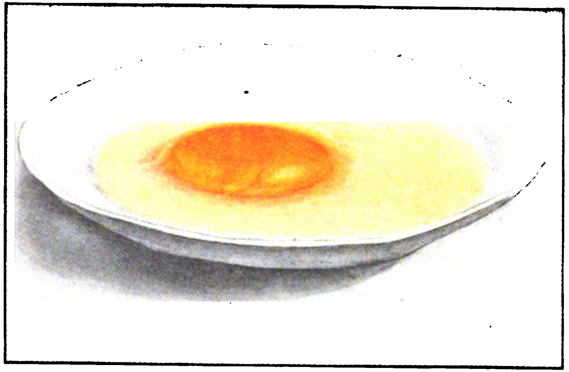

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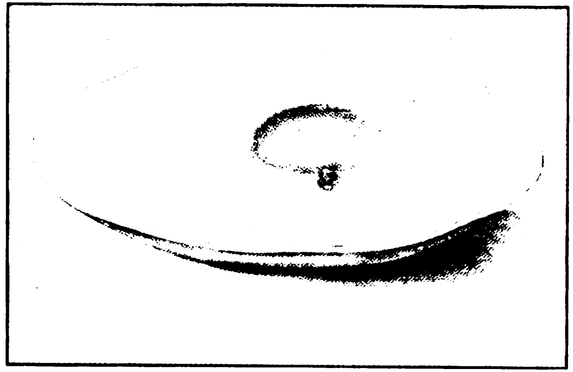

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FIG. 11.— *Rate of evaporation of hens' eggs*

1 to 9. Eggs that have been held for one day, one week, two weeks, three weeks, four weeks, five weeks, six weeks, seven weeks, and eight weeks, respectively. The eggs were kept at a living-room temperature of about 70° F., in an open pasteboard carto.:. There was no breeze blowing over the eggs, and each egg illustrated is typical of several eggs that were examined at each stage; therefore this series represents the normal results of such holding

10 to 12. Eggs held for twelve weeks, one week, and one-half week, respectively, at a temperature of 40° F. This is a very good temperature at which to hold eggs for short periods. Even at twelve weeks of age (section 10), the egg is less evaporated than at four weeks of age, if held at a living-room temperature of 70° F. (section 5). Eggs may be held for two weeks at 40° F. without much change

13 and 14. Each of these eggs has been held for six weeks at a temperature of about 50° F. The porous shell of the second egg (14) has caused more rapid evaporation. The porosity of the shell may be easily distinguished in candling

15 and 16. These eggs have been held for five weeks and for two and one-half weeks, respectively, at a temperature of 50° F. It should be noted that the evaporation is more rapid than that which took place at 40° F., but much slower than that at 70° F.

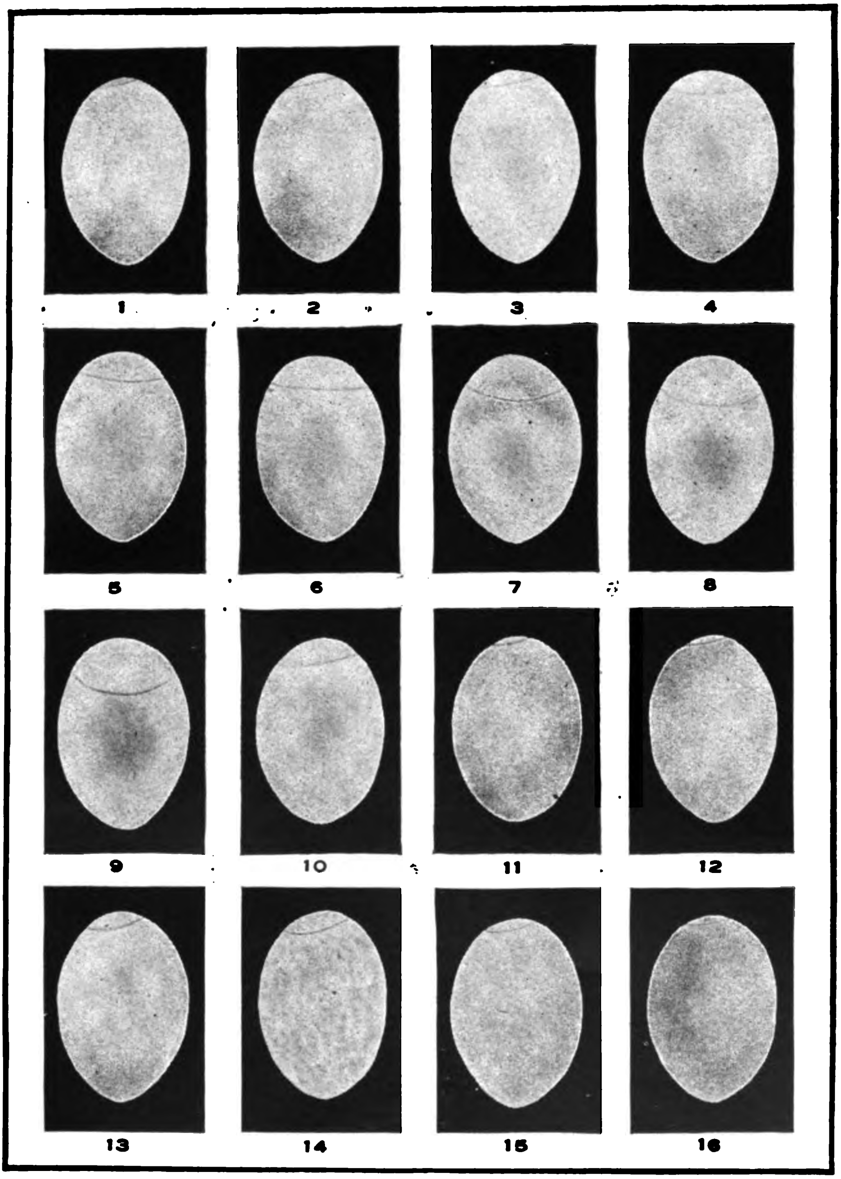

FIGURE II

reflection of light, which follows it. This is the outer end of one of the chalazæ, which extends out close to the shell and is often mistaken for a meat spot (Plate I, sect. 8). The meat spot, however, is darker and has no reflection of light on its edge. In the fresh egg the yolk appears to be suspended well up in the albumen, moves freely, and its deeper color shades very gradually into the normal tone of the albumen. The albumen has a pink color, the intensity depending on the shell pigment.

The appearance of the opened fresh egg should also be studied (Plate II, sect. 25). The color of the yolk is affected largely by the feed given; yet, if the egg is fresh, the yolk will have in general a lighter appearance than it will after the egg has been kept for a while. A dark yolk usually denotes heating. The germinal disk will appear as a minute spot on the yolk, as shown in the upper right-hand corner of the yolk (Plate II, sect. 25). This disk will show, no matter whether the egg is fertile or infertile, although usually it is not so distinct in the latter case. It is usually light-colored, but may be dark. The yolk should stand up round, due to the strong vitelline membrane. This membrane should show no wrinkles nor signs of weakening that would allow the yolk to flatten or to flow into the albumen. The albumen is almost transparent and stands up firm around the yolk. The very thin inner layer of albumen clings to the vitelline membrane of the yolk and is hardly visible. The chalazæ are firm, usually twisted hard, and relatively close to the yolk. The middle layer of albumen surrounds the yolk closely and appears as a somewhat jelly-like mass merging gradually into the watery outer layer which lies next to the shell. No cloudiness nor color should appear in the albumen of a fresh egg. The contents of the egg should have practically no odor except the slight odor of lime, which can usually be detected. Fresh eggs are usually free from bacteria, or nearly so, and the chemical analysis is nearly constant.

INTERNAL FACTORS AFFECTING THE INTERIOR QUALITY OF EGGS

When eggs are first laid they normally possess the characteristics of perfect fresh eggs, as has been described. There are, however, various abnormalities that may occur, and, since these abnormalities are usually detrimental to the quality of eggs, some of them will be described here.

GENERAL CONDITIONS

The physical condition of the bird probably has an effect on the quality of the egg. It is thought that the size and color of the yolk, percentage of moisture, condition of the shell, firmness and amount of the albumen,

and various other features, are affected by food, season of the year, condition of the bird, and the like.

Green food, yellow corn, and general ranging seem to transmit a deep color to the yolk. Such food as white corn, buckwheat, and wheat, lack of exercise, and poor health, seem to produce a pale yolk. Any one of these factors may give distinct results. Excessive quantities of green food, such as rape in the early spring, sometimes seem to have a disastrous effect on eggs, causing the yolks to be very dark in color and to possess an undesirable odor. Onions readily affect the odor and the flavor of eggs. Cabbage also does this to some extent, as do a few other foods. Many persons claim that they can detect a difference in the flavor of eggs when hens are allowed free range where they have access to bugs, worms, and the like.

Eggs produced during the summer seem to have a more watery albumen than those produced during the spring. Watery eggs seem to be of lower quality, and undesirable for cold storage or long holding. In candling such eggs, the yolks seem to float lower in the albumen and appear slightly darker than in spring eggs.

Certain hens probably have an inherited tendency to produce eggs of inferior quality. If this is true it will be likely to remain as a characteristic of the line of descent, and the flocks must be carefully culled in order to eliminate such undesirable birds.

OVARIAN CONDITIONS

Double-yolk eggs

Detailed reports have been made by Glaser of double-yolk eggs resulting from the joining of two yolk sacs during their development. These sacs gradually develop one common blood supply, their growth becomes identical or nearly so, and both yolks mature and drop into the oviduct at about the same time. It is supposed that two yolks may develop within the same yolk sac, and sometimes within the same vitelline membrane.

Multigerminal disks

Many yolks have more than one germinal disk, these showing as several round light spots on the surface of the yolk. Only one of these disks usually shows development when an egg is incubated.

Misplaced yolks

Yolks are sometimes dropped into the oviduct before they are mature, and thus appear as abnormal yolks in the completed egg. Sometimes yolks are dropped outside the oviduct into the body cavity; they are then probably absorbed by the body tissues in most cases.

Blood clots

Perhaps the commonest of the faults arising in the ovary is the blood clot (Plate III, sect. 23, and Plate V, sect. 40). This is usually caused by the rupture of a blood vessel when the yolk sac splits in order to allow the escape of the mature yolk into the oviduct. This rupture may be the result of such abnormal circumstances as a split occurring in some part of the yolk sac other than at the suture line, or a crossing of the suture line by a blood vessel. Ruptures of other tissues may have a similar effect. Blood clots seem to occur relatively oftener during the first laying period of pullets and during the spring period of heavy production than at other times. This is probably due to the extra heavy strain on the egg organs at these times.

The clot of blood adheres to the yolk as it passes through the oviduct, and if it is of good size it may be distinctly seen when candling. A blood clot can be distinguished from other spots by its bright red color and by the fact that it is on the surface of the yolk and moves only with the yolk. A blood clot alone shows as a distinct spot through the shell, not as a diffuse-colored area of the egg. When the egg is opened the clot can be distinctly seen. If it is removed, the egg is suitable for use as food unless otherwise defective. An ordinary blood clot does not color the albumen; if the albumen is colored, the egg is termed a bloody egg. The illustrations in Plates III and V, sections 23 and 40, respectively, show bloody eggs as well as blood clots. The egg opened (Plate V, sect. 40) is only slightly bloody.

Because of the presence of blood in these eggs they are often confused with incubator eggs, and customers refuse to use them for any purpose. Hotel stewards require that all their eggs shall be candled for the purpose of eliminating the eggs with blood clots. The producer or dealer should make use of many of them and avoid the waste. It is believed that certain hens have a tendency to produce these clots, and by culling such birds from the flock the percentage of blood-clot eggs can be greatly reduced. Blood clots are probably detrimental to the keeping quality of eggs.

OVIDUCT CONDITIONS

Body-heated eggs

An egg is forced through the oviduct by the peristaltic action of the muscles in the oviduct wall. Sometimes, apparently due to fright, this action ceases temporarily, and the egg is held in the body of the fowl for several days after it is completed. This keeps the egg at body temperature, and incubation begins. If the egg is fertile, the results are disastrous at once. If the egg is infertile, of course the results are not so serious and the egg may be fit for use when laid, depending on the extent to which the egg was infected while being held in the body of the hen.

Eggs within eggs

When an egg has passed through the oviduct and is ready to be laid, a reverse peristaltic action may be incited in some way, and the egg will be forced back up the oviduct until normal forces again push it along its regular course. In this way one yolk may be enveloped with two complete sets of albumen, shell membranes, and shell. Three sets have been known to be formed over a single yolk, probably in this way. Sometimes other yolks are met by the ascending egg and the whole is surrounded by one set of albumen, shell membranes, and shell. The first egg, in any case, is usually an abnormally small one, and this may often account for the reversal of the peristaltic forces.

Yolk substitution

Grains or fragments of other foreign substances may be forced up the oviduct from the cloaca. This has been known to occur, and during the normal return of such substances the oviduct glands have secreted albumen, shell membranes, and shell, forming a complete egg except that a foreign body has been substituted for the yolk.[4]

Foreign substances within eggs

Due to causes similar to those resulting in yolk substitution, grains and other foreign substances are sometimes found floating in the albumen. If an egg has previously been broken in the oviduct, the broken contents may gradually harden and cling to the oviduct walls. Later they may become detached and pass along with an egg. In this way various forms of dried yolk and albumen may be deposited in eggs; rings of dried yolk and albumen have been observed, as well as various other peculiar shapes.

Intestinal worms within eggs

Intestinal worms are sometimes found in eggs. They apparently gain access to the oviduct from the large intestine and are later included in an egg as it is being formed. These worms vary in size and form, but are usually white in color.

Double-yolk and connected eggs

If one yolk drops into the oviduct shortly after another, even though this is due to no abnormal condition of the ovary, the one secretion of albumen may surround both yolks and form a double-yolk egg as previously described. A few cases of triple-yolk eggs, apparently formed in the same way, have also been described.[5] If the yolks are too far apart to be

[4] Many interesting experiments have been conducted along this line by Dr. Raymond Pearl.
[5] Such eggs have been found by Dr. Raymond Pearl.

enclosed as one egg, they may still remain connected in various ways. A small amount of albumen, with shell membranes and shell, may connect the two complete eggs. The two adjacent chalazæ may be either continuous or separate. Sometimes only the shell membranes connect the eggs, neither albumen nor shell being present.

Soft-shell eggs

Eggs are sometimes produced having only a very thin shell or having no shell material at all. Eggs of this type are the result of a condition that may be caused by a lack of lime in the glands of the uterus or by one egg forcing the next egg out of the body of the fowl before the shell can be formed. Soft-shell eggs occur, therefore, most frequently during the period of heavy egg production.

Meat spots

Particles appearing like pieces of liver are often found floating in the albumen (Plates I and II, sects. 8 and 28, respectively). On closer examination these particles seem to be pieces of the dead glands of the oviduct wall, and, since they occur very often, they are thought to be fragments of this waste tissue. In candling eggs it will be noted that meat spots appear very dark and float near the shell. They may be of various shapes or may consist of several very small, floating specks. They lack the characteristic red appearance of a blood clot, and are free from the yolk. When an egg having this peculiarity is broken open, the meat spot is sometimes found attached to one of the chalazæ or it may float entirely free. If it is removed, the egg is satisfactory for use as food unless otherwise defective. Such eggs are treated on the market in the same manner as are those having blood clots.

Bloody eggs

The oviduct often becomes injured and irritated so that blood is exuded with the albumen, making the albumen appear distinctly bloody. This condition may appear throughout an egg or in certain parts of it, as already mentioned and as shown in Plates III and V, sections 23 and 40, respectively. Bloody eggs are commoner with pullets just beginning to lay or during the heavy laying period than at other times, as in the case of blood clots, and are probably due largely to over-exertion of the oviduct. The blood in the albumen is often concentrated about the chalazæ, but this is not always the case. Certain individuals of the flock are generally responsible for all the bloody eggs, and it is well to remove these fowls when they are discovered. It is usually impossible to remove the affected part of the

albumen; therefore the egg is useless. Because of this, bloody eggs are a more serious loss than those having blood clots or meat spots.

Loose shell membrane

Sometimes fragments resembling parts of the shell membrane are found floating in the albumen. These are apparently due to slight secretions of the shell membrane glands in the isthmus, which have formed little fragments of membrane that cling to the walls of the isthmus. When the next egg passes through the oviduct, these membranous fragments are carried along and float free in the albumen. They are not detrimental to the quality of an egg, but eggs bearing them are usually discarded because of their suspicious appearance to persons not understanding the cause. The term "tapeworm" is a popular one given by egg candlers to this type of egg, because of its peculiar appearance.

EXTERNAL FACTORS AFFECTING THE INTERIOR QUALITY OF EGGS

EVAPORATION

As soon as an egg is laid, the water begins to evaporate through the pores of the shell. The rate at which moisture is lost is influenced by the humidity and temperature of the air surrounding the egg, the rate at which this air is moving, and the structure of the shell and the shell membranes. As evaporation continues, air replaces the moisture within the egg and the air cell is gradually enlarged. The rate of evaporation taking place at living-room temperature compared with that taking place at cooler temperatures is shown in Figure 11. A simple method for testing the degree of evaporation is illustrated in Figure 7, on page 504.

Excessive evaporation of eggs is caused by dry air passing rapidly over them. Warm air will cause more rapid evaporation than cold air. At any given temperature the amount of evaporation will be decreased by increasing the moisture in the air. The amount of moisture must not be excessive, however, or the eggs will become musty and mold spots will develop (Plate VI, sect. 13). With a given amount of moisture in the air, the danger from molding will be lessened by lowering the temperature of the air. Eggs vary considerably in the relative thickness and weight of their shells. The thicker shells may be expected to directly limit the rate at which eggs will evaporate; this leads to the conclusion that for this reason alone fowls should be supplied with plenty of lime. It may also be expected that the structure of the shell membranes influences the rate of evaporation (Fig. 5, page 501). Very porous shells may be easily detected by candling or by the general appearance of

Plate III.— Candling appearance of market eggs

17. A live embryo after twelve hours of incubction. Note the slightly raised yclk, darkened by heat, and the embryo on the upper surface of the yolk

18. A live embryo after five days of incubation. Note the embryo and blood vessels, and the dark mixed yolk

19. A live embryo after twelve days of incubation. Note the clouded contents, with few large blood vessels in view, and the enlarged air cell

20. A live embryo after eighteen days of incubation. Note the general dark appearance, the outline of the chick, and the enlarged air cell

21. A dead embryo after five days of incubation. Note the ring or band of blood, the enlarged air cell, and the clouded appearance

22. An infertile egg after five days of incubation. Note the distinct yolk, the enlarged air cell with a dark boundary, and the general heated appearance

23. A bloody egg and blood clot. Note the bright red clot on the yolk, and the general redness of the albumen

24. A soft boiled egg. Note the slaty blue color

Plate IV.— Opened appearance of market eggs

33. A live embryo after five hours of incubation. Note the indistinct circle around the embryo, the heated and flattened yolk, and the watery and darkened albumen

34. A live embryo after twelve hours of incubation. Note the distinct rings around the embryo, the heated and flattened yolk, and the watery and darkened albumen

35. A live embryo after five days of incubation. Note the embryo and blood vessels, the ruptured vitelline membrane, and the watery nature of the albumen

36. A live embryo after twelve days of incubation. Note the distinct form of the developing chick

Plate V.— Opened appearance of market eggs

37. A live embryo after eighteen days of incubation. Note the fully shaped chick, with the embryo sac attached

38. A dead embryo after five days of incubation. Note the ring or band of blood, the mixed yolk and albumen, and the signs of deterioration

39. An infertile egg after five days of incubation. Note the heated appearance of the yolk, the very watery contents, the slightly colored albumen, and the very weak vitelline membrane

40. A bloody egg and blood clot. The blood clot is adhering to the yolk. A small part of the albumen is bloody, but the greater part of the egg is perfectly normal

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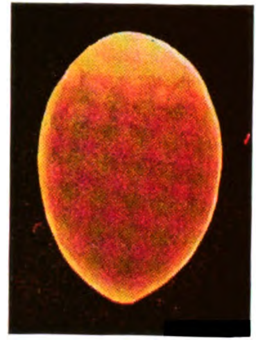

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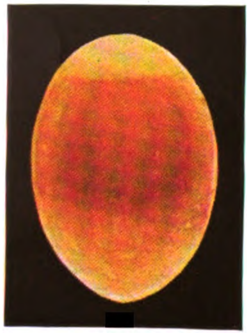

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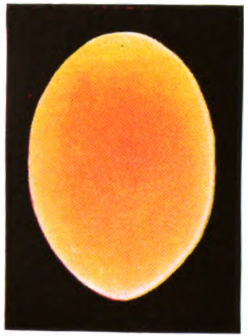

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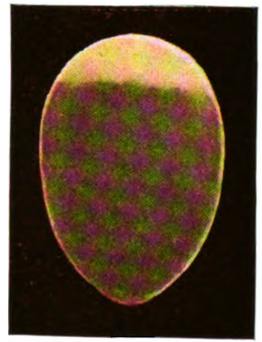

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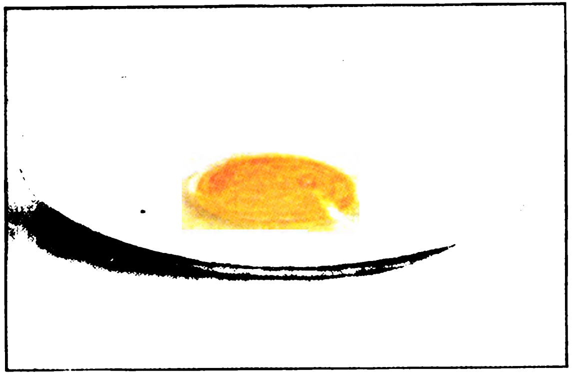

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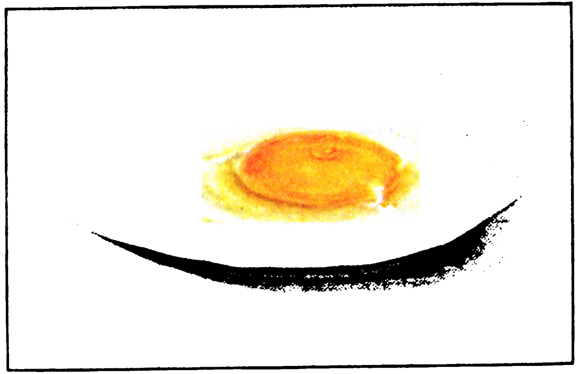

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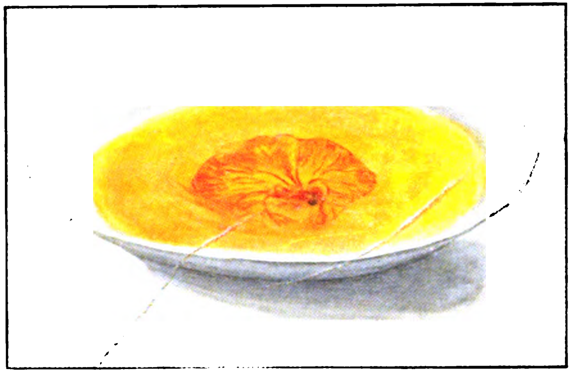

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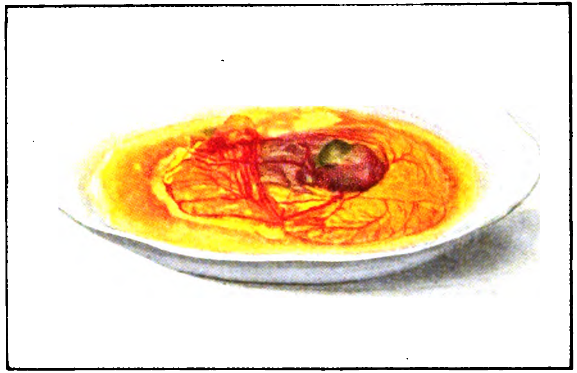

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weakness or transparency. Since individual fowls may possess the special characteristics of laying eggs of a definite type, by careful selection it should be possible to eliminate those fowls that produce the eggs most liable to excessive evaporation.

A cellar or a refrigerator is ordinariiy the most desirable place available for keeping eggs. In the average cellar excessive dampness may be avoided by placing the eggs on a table or a shelf, thus keeping them at a short distance above the floor. Eggs may usually be held for two or three weeks under these conditions, with very slight evaporation. Kitchens, sheds, or similar rooms should be especially avoided, as is shown by reference to Figure 11. If eggs are to be held for several days, they should be kept in pails, boxes, or similar receptacles, which will prevent the free circulation of air through the packages and yet will allow a moderate amount of ventilation. If eggs are held in cool, dry air long enough, all the moisture will evaporate and the yolk and albumen will become a dried mass. No other deterioration will take place.

Yolk stuck to shell

If an egg is allowed to remain in one position too long, the yolk will gradually rise and stick to the shell membranes (Plate VI, sect. 12). This process is hastened and nearly always accompanied by evaporation. After the yolk is stuck to the shell membranes, if the egg is in a moist location, molds will rapidly develop at the spot where the yolk is stuck. During the first stages the yolk can usually be shaken loose without rupturing the vitelline membrane, but later this is impossible. Eggs in this state are very seldom used except for animal food or for fertilizer. This condition may be avoided by placing eggs on end in storage, by keeping them at a temperature of 40° F. or lower, or by turning them regularly. At room temperature at least three or four weeks will be required for this condition to develop; at warmer temperatures it may occur in less time.

TEMPERATURE

The effect of heat on eggs depends largely on whether the eggs are fertile or infertile. It has been found that the germ of a fertile egg will begin to develop at a temperature as low as 72° F. Whether the development of the germ takes place at this low temperature or at a higher temperature, the results are essentially the same, except that at the low temperature the development is very slow and the germ soon dies. Disintegration of the egg contents begins immediately after the death of the embryo. This disintegration cannot begin ordinarily without the presence of a dead embryo. The presence of males in the flock is the

cause for nearly all the rotten eggs, as well as a great proportion of the other inferior grades on the market. As noted before, the eggs are fertilized at the upper end of the oviduct. By the time the egg has reached the lower end of the oviduct, the germ is ready for development, and any further application of heat will cause the embryo to begin growth.

Heating at incubation temperature

Every hour during which an egg is held at incubation temperature (95° to 110° F.) seriously affects its quality. If the egg is fertile, an interesting series of changes takes place very rapidly.

Fertile egg after five hours of incubation.— Even after five hours of incubation the candler can ascertain that the egg has been incubated. He can detect a tiny embryo on the upper surface of the yolk, and the yolk floats higher in the albumen than in a fresh egg. When the egg is broken open (Plate IV, sect. 33), it will be noted that the yolk appears a little darker and that an indefinite ring is beginning to form around the germinal disk. The appearance of this ring varies in different eggs, but its presence denotes a developing embryo. The albumen is becoming darker and more watery, and the vitelline membrane is weakening, allowing the yolk to flatten. This egg is suitable for food purposes.

Fertile egg after twelve hours of incubation.— After twelve hours of incubation, the embryo is clearly discernible through the shell (Plate III, sect. 17). It usually appears at the upper edge of the yolk and is distinguished as a part of the yolk having a deeper red color. These early stages of development are very difficult to note with brown-shelled eggs. The yolk usually floats higher in the albumen than before. When the egg is opened (Plate IV, sect. 34), two or three rings around the germinal disk are clearly distinguishable. The yolk has more of a heated appearance; that is, it is darker in color and is still more flattened. The albumen has more color and is more watery. The chalazæ begin to merge with the middle layer of albumen. Eggs at this stage of development are still good for cooking purposes, and are better than the average eggs received direct from many farms during hot weather.

After noting the changes taking place in these two classes of incubated eggs, one can realize how serious it is to allow broody hens to remain on the nests even for one day. If many hens lay eggs in the same nest, it is easy to estimate the length of time the first egg laid has been heated during the day. This time often totals two to eight hours. The contents of these eggs break down quickly after removal from the nest, and they rapidly become unfit for food.

Fertile egg after five days of incubation.— The blood vessels can now

be seen by the candler and the upper part of the egg begins to appear clouded (Plate III, sect. 18). The vigor of the embryo may be judged approximately by its appearance through the shell. The air cell is increasing slightly in size, although this varies greatly with the humidity of the air. On opening the egg (Plate IV, sect. 35), the developing embryo and the network of blood vessels are seen on the surface of the yolk. The vitelline membrane is usually ruptured and the yolk contents flow out into the very watery albumen, giving the whole a light yellow color. The egg is absolutely unfit for food consumption and can be used only as meat food for stock or for other commercial purposes.

Fertile egg after twelve days of incubation.— After twelve days of incubation, the contents of the egg appear materially darker to the candler than at the five-days period (Plate III, sect. 19). The blood vessels and the embryo are indistinct. The few blood vessels appearing near the air cell are much enlarged and are filled with blood. The whole egg is clouded, and the air cell is usually considerably enlarged. The opened egg (Plate IV, sect. 36) displays the form of the head, the heart, and some other parts of the chick. Of course these eggs cannot be used for human food.

Fertile egg after eighteen days of incubation.— By the eighteenth day of incubation the chick must be very nearly developed if it is to leave the shell on the twenty-first day. To the candler the whole egg appears darkly clouded, and only the dim outlines of the chick may be discerned just beneath the air cell (Plate III, sect. 20). The air cell is greatly enlarged, and the lower boundary is very irregular. The motions of the chick may be seen. The opened egg discloses the well-developed chick, with the embryo sac attached (Plate V, sect. 37). Specimens of eggs of this kind are brought to the markets, and, needless to say, they are useless except as fertilizer, or perhaps as animal food if used when absolutely fresh. Deterioration begins immediately after the death of the chick, and of course this has affected the condition of the egg by the time it reaches the market.

Dead germ after five days of incubation.—If for any reason the embryo dies during the period of its growth, the common term "dead germ" designates the grade of egg produced (Plate III, sect. 21). The dead germ shown here died after nearly five days of incubation. The characteristic feature of the dead germ is the blood ring, which is formed by the settling of the blood in the outer boundary of the network of blood vessels. This network of blood vessels is best shown in Plate VI, section 35. The blood ring may be small and regular, or large and very irregular and even incomplete. The dead embryo itself appears as a small dark spot, usually stuck to the shell or partially attached to the disintegrated tissues. The air cell is usually somewhat enlarged. When the egg is

opened the blood ring may show distinctly if it is small; or, if larger, it may appear as an irregular or broken band of blood (Plate v, sect. 38). The embryo itself usually appears as a small dark lump, until deterioration has proceeded sufficiently to obliterate it entirely. The yolk and the albumen are mixed at this stage, and the egg contents are very watery. An egg of this type is of no use for human consumption, and after it has been held for a while decomposition rapidly sets in and the egg can be used only for a few commercial purposes.

In the very early and the very late stages of development the dead embryos cannot be detected by the presence of the blood ring. Of course, if the candler detects a spot on the yolk denoting a developing embryo, unless the temperature is approximately 100° to 105° F., he may know that the germ is dead. Dead chicks in the shell can be easily detected by candling. Ordinarily, incubated eggs are considered suitable for food purposes until blood vessels begin to appear or deterioration begins, unless some other factors, such as odor, flavor, and the like, limit their use.

Infertile egg after five days of incubation.— If eggs are infertile, the greater part of the difficulty in properly handling them is avoided. Incubation heat affects an infertile egg only slightly (Plate III, sect. 22). The yolk is slightly darkened by the heat, and as a rule at this stage it does not float so high in the albumen as before. The air cell is enlarged, and its inner boundary is usually dark red. The whole egg displays the characteristic appearance of a heated egg — the orange-red tint. There is a definite boundary between the yolk and the albumen, rather than the gradual shading noted in the fresh egg. The opened infertile egg is distinguished by a very watery albumen which is slightly colored, and by a weak vitelline membrane which allows the yolk to flatten (Plate v, sect. 39). The vitelline membrane often appears wrinkled and breaks very easily. The chalazæ are often hardly visible, due to their merging with the middle layer of albumen. The color of the yolk is dark, denoting heating. The odor of the opened egg is sometimes unpleasant, although it is usually impossible to detect any change.

Very often candlers, especially those of little experience or those using a poor light, mistake eggs having very small embryos for infertile eggs. If the eggs are to be used for cooking purposes, the candler must be very careful and should use at least a twenty-candle-power light. Infertile eggs are suitable for food uses unless they have been held so long that deterioration has started; in that case they are of value only for commercial purposes. Infertile eggs should be handled carefully and used for purposes for which mere freshness is not important so long as the eggs are good. They are satisfactory for nearly all cooking purposes, and are

not usually unsatisfactory for frying or scrambling, even after having been removed from the incubator two or three weeks previously, if kept under proper conditions.

It is interesting to compare the infertile incubated egg with the series of fertile incubated eggs. One can thus realize the danger due to fertilization in market eggs. If a fertile egg is to be marketed in good condition, no cost should be spared in adopting every possible precaution. Infertile eggs do not require such extreme care.

Heating at temperatures below incubation temperature

The effect of low heat on eggs varies with the fertility or the infertility of the eggs. The difference here is not so marked as at incubation temperatures, but in all phases of egg marketing any detrimental heating seems to have a much more serious effect on the interior quality of a fertile egg than on that of an infertile egg. For instance, a small degree of heating will usually cause a fresh egg to become a "light float" (Plates I and II, sects. 4 and 26, respectively). This will occur whether the egg is fertile or infertile, but the fertile egg will reach this stage and pass it much more rapidly than the infertile one. In studying the effect of heat on market grades of eggs, it is necessary also to consider the effect of evaporation, which has already been explained.

"Light float" and "heavy float" are trade names that are applied to eggs of a distinctly lower grade than fresh eggs. For consideration in this bulletin, all the inferior grades of edible eggs resulting from slow heating and evaporation are classed as light floats or heavy floats (Plates I and II, sects. 5 and 27, respectively). The term was probably first adopted by market men as indicative of the buoyancy of the yolk in the albumen. In the light float the yolk is not quite so buoyant as in the fresh egg, but is more so than in the heavy float. Light floats and heavy floats are the commonest grades of market eggs received from the general farms, where, in fact, most of the eggs are produced. The methods that the average farmer now follows do not allow the holding of eggs for a week and still having them stand the test for fresh eggs. Most of the markets make much finer distinctions than these three grades — fresh, light float, and heavy float — but these are the main subdivisions, and further classifications may be made at will. By thoroughly understanding these three grades, one can easily adapt himself to any other system that he may wish to follow.

Light float.— The light float, as it appears to the candler, shows an enlarged air cell and a darkened yolk. The yolk has a more definite boundary than in the fresh egg (Plate I, sect. 2), and sinks lower in the albumen. The whole egg has a darkened and heated appearance. No

embryo spot is visible on the yolk; if there were such a spot, the egg would have to be classed as a dead germ. Light floats are very difficult to distinguish from infertile incubated eggs. The air cell in the light float is in most cases larger, due to the drier air in which it has usually been held; but otherwise the appearances are nearly identical and the two grades are usually classed together. Light floats do not deteriorate so rapidly as do infertile incubated eggs, and consequently they are usually sold separately. When the light float is opened, it usually appears in much better condition than the infertile incubated egg, as may be seen by comparing the appearance of the two eggs (Plates II and V, sects. 26 and 39, respectively). The yolk of the light float is slightly flattened and is a trifle darker than that of the infertile incubated egg. The albumen of the light float is becoming somewhat watery and slightly colored, but is much better than that of the infertile incubated egg. The light float is just beginning to show the effect of slight heating, and, while it is still in good condition, it deteriorates rather rapidly after it has reached this first stage. The flavor is but slightly affected and can hardly be distinguished from that of a fresh egg. Light floats are good for practically all food purposes if used at once, but they should not be kept for a long period, even under proper conditions.

Heavy float.— The heavy float is a more advanced stage of the changes seen in the light float (Plates I and II, sects. 5 and 27, respectively). The air cell is somewhat larger, and the yolk is much darker and usually lower in the albumen. The position of the yolk varies considerably, but the typical position is in the lower part of the egg. The inner membrane around the air cell is often loose and sometimes broken, allowing the contents to shake. To the candler the whole egg appears heated. When the egg is opened, the yolk of the heavy float is usually much darker than that of the light float, and is very often somewhat mottled owing to the localization of the heat effect. The vitelline membrane is very weak, and often breaks when the egg is being opened. The yolk contents sometimes begin to seep through the membrane, either flowing through a very small opening and extending needle-like into the albumen, or mixing with the albumen and forming an indefinite colored area around a large part of the yolk. The albumen is very watery and slightly colored. This grade of eggs includes those which have been heated and which are too poor to be light floats and yet are good enough for human consumption. It is about the last stage of deterioration for an infertile egg, unless it begins to rot, due to the action of bacteria; but this latter condition is improbable. Fertile eggs pass by this stage quickly and become rots. Large numbers of eggs of this type are marketed with fresh eggs. Their condition could easily be avoided by proper management,

such as removing broody hens, gathering eggs regularly, keeping them in a cool place, marketing regularly, and the like.

Freezing and chilling

If an egg is frozen, the contents usually expand sufficiently to crack the shell. The crack usually extends the length of the shell, reaches through the shell membranes, and remains open, thus allowing easy infection of the egg contents. The cellular structure of the egg contents is also broken down to some extent, and the egg will not keep so well under any conditions as would a normal egg. Chilling has an effect similar to freezing on the keeping quality of eggs, although this effect is not always so immediate. It is necessary to collect eggs twice daily during very cold weather, and care should be taken to prevent chilling while the eggs are being held or shipped.

Boiling

Eggs are sometimes dipped into hot water in order to prevent their being used for hatching. This is a foolish and unjust practice. It is sometimes done with the purpose of deceiving the dealer concerning the freshness of eggs, but for this purpose it has to be done so carefully that it is very seldom undertaken. If an egg is dropped into water of just the right temperature, a very thin film of hardened albumen is formed just inside the shell, and this makes the egg yolk appear relatively less distinct and the egg consequently fresher than it really is.

A medium-boiled egg has the appearance shown in Plate III, section 24. The harder the egg is boiled, the more opaque it will appear. The size of the air cell is determined, of course, by the amount of evaporation that had taken place before the boiling was done. Sometimes the same results may be obtained if an egg is allowed to lie exposed to the direct rays of the sun during a very hot day.

MOISTURE

It has already been shown that the lack of moisture in the surrounding atmosphere causes evaporation in eggs. On the other hand, though not so frequently, too much moisture has results that are just as serious.

Musty eggs

When eggs are held for a long time in an atmosphere that is too humid, such as in some cold storage warehouses, they may develop a musty odor and flavor. This condition is increased on heating. The cause for the development of mustiness in eggs is not known, but it seems to be due to the presence of an excess of moisture for a long period.

Mold spots

Molds often develop inside the shell membranes of eggs (Plate VI, sect. 13). These molds appear to the candler either as small dark dots or as larger dark areas. The mold developments are often collected along the line of the air cell or along checks in the shell. When the shell is opened, the mold is usually found adhering to the inner shell membrane, appearing like a lump of dense albumen. Mold-spot eggs are, of course, unfit for food. The formation of mold spots can be prevented by avoiding an excess of moisture where the eggs are kept.

BACTERIAL INFECTION

The action of various types of bacteria on the contents of eggs causes the development of various grades of market eggs. The entrance of bacteria into an egg may possibly take place before the egg leaves the body of the fowl; but usually the bacteria enter when the egg becomes checked or after it comes into contact with moisture, after which the bacteria seem to be able to penetrate the shell and the shell membranes. The best way to avoid bacterial deterioration of eggs is to avoid fertilization, and then to keep the eggs clean, dry, and whole by careful handling. An egg is naturally protected by its bactericidal albumen, but this is not always sufficient.

Soiled eggs

Eggs that have become soiled have probably been moistened at the same time. This moisture, in mud, droppings, wet litter, or grass, is laden with bacteria of various types. These gain access into the interior of an egg, enter the yolk, and develop there. Such a condition can be avoided only by having the grounds, houses, nests, gathering pails, and the like, clean. In cleaning eggs, great care should be taken not to wet the shells any more than is necessary. This can be accomplished by wiping the shells with a slightly dampened cloth and some abrasive substance such as bon ami, sapolio, or something of similar nature. No acids should be used. Eggs that have not been soiled or moistened will keep better than those that have been cleaned; therefore cleaned eggs should be handled carefully and disposed of as quickly as possible.

Rots

The development of bacteria within an egg may assume many different aspects, but usually, and especially in the case of fertile eggs, the product is one of a series of rots. This greater susceptibility of fertile eggs is due to the usual presence of a disintegrating dead germ. These grades of rots vary considerably in quality and appearance, but they have been

PLATE VI.— CANDLING APPEARANCE OF MARKET EGGS

9. *A home-preserved egg. Note the medium-sized air cell and the fresh appearance of the yolk*
10. *A No. 1 cold storage egg. Note the enlarged air cell and the slightly darkened yolk*
11. *A No. 2 cold storage egg. Note the very large and loose air cell, and the darkened yolk with a very distinct boundary*
12. *A stuck yolk. Note the spots where the yolk adheres, and the enlarged air cell*
13. *Mold spot. Note the small mold spots on the shell membrane*
14. *White rot. Note the slimy and mixed appearance of the egg contents, and the enlarged air cell*
15. *Mixed rot. Note the darkened and mixed contents, and the broken air cell*
16. *Black rot. Note the very dark contents, and the large, loose air cell*

PLATE VII.— OPENED APPEARANCE OF MARKET EGGS

29. *A home-preserved egg. Note the pink and watery albumen, and the flattened and slightly darkened yolk*
30. *A No. 1 cold storage egg. Note the well rounded yolk, and the slightly watery albumen with a slightly darkened tint*
31. *White rot. Note the mixed and very watery contents, and the light yellow color*
32. *Mixed rot. The contents are of various colors, mixed, and very watery*


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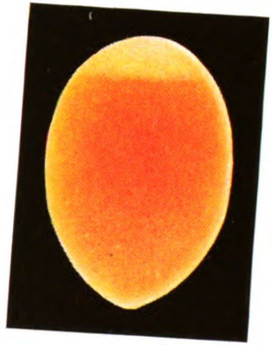
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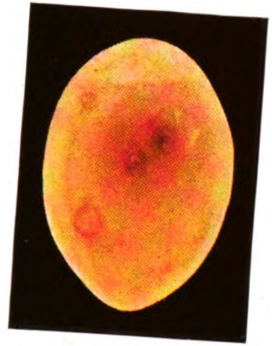
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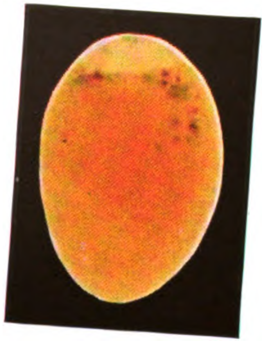
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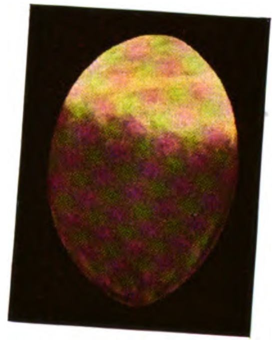
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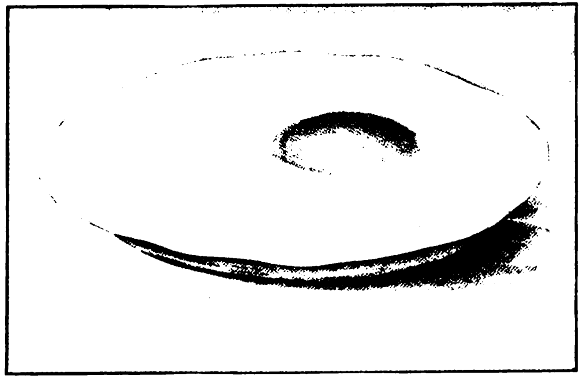

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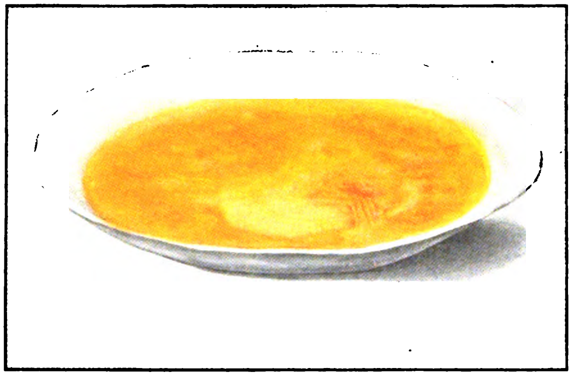

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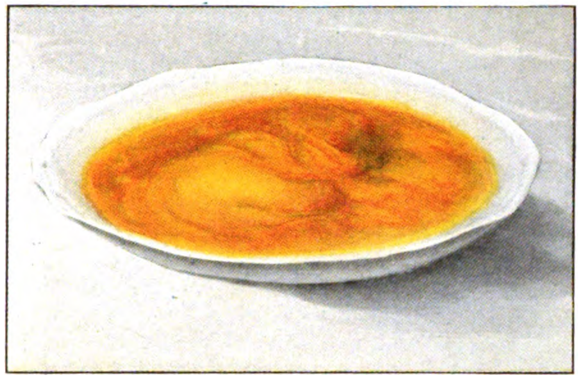

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roughly subdivided into white rots, mixed rots, and black rots. Eggs of all these grades are absolutely unfit for food purposes. Rots can be largely prevented by avoiding the possibility of fertilization and the bacterial infection of an egg after it is produced. It is only in very rare cases that an egg has been found to be seriously infected with bacteria when it left the body of the hen.

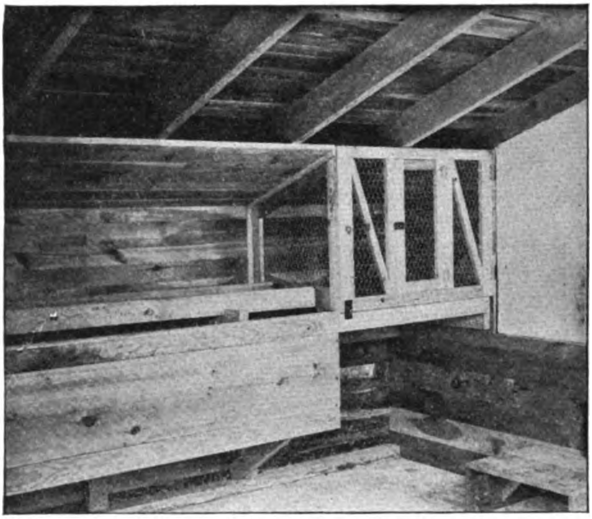

FIG. 12.—*Care should be taken to insure clean, well-ventilated houses and plenty of clean nests. A good location for the nests is under the dropping boards, as shown in this interior view of a good poultry house*

White rot, or sour egg.—The white rot—often termed sour, or addled, egg—is about the first stage of bacterial decomposition (Plates VI and VII, sects. 14 and 31, respectively). To the candler an egg in this condition appears to have an enlarged air cell, but otherwise it seems to be very nearly normal. By close inspection the candler can detect the homogeneous nature of the egg contents in contrast with the normal appearance of the yolk and the albumen. The air cell is often broken and the egg contents have a slimy appearance. As the egg is twisted before the candle, the mixed dark and light streaks pass the line of vision and usually show distinctly that the egg is addled, or thoroughly mixed. When the egg is opened, the contents are usually light yellow in color, very watery, and mixed (Plate VII, sect. 31). Parts of the vitelline membrane are

FIG. 13.—*Egg pail. In order to prevent eggs from becoming dusty or wet, it may be advisable to use a special covered egg pail*

usually visible, and parts of the yolk may be partially solidified. The egg usually has a sour odor, and for this reason it is often termed a sour egg.

Mixed rot.— When the contents of the white rot have darkened perceptibly, representing an advanced stage, the egg is usually termed a mixed rot (Plates VI and VII, sects. 15 and 32, respectively). Some parts of the contents may be darker than others. The air cell is broken. When the egg is opened, the contents are found to be very watery, and various

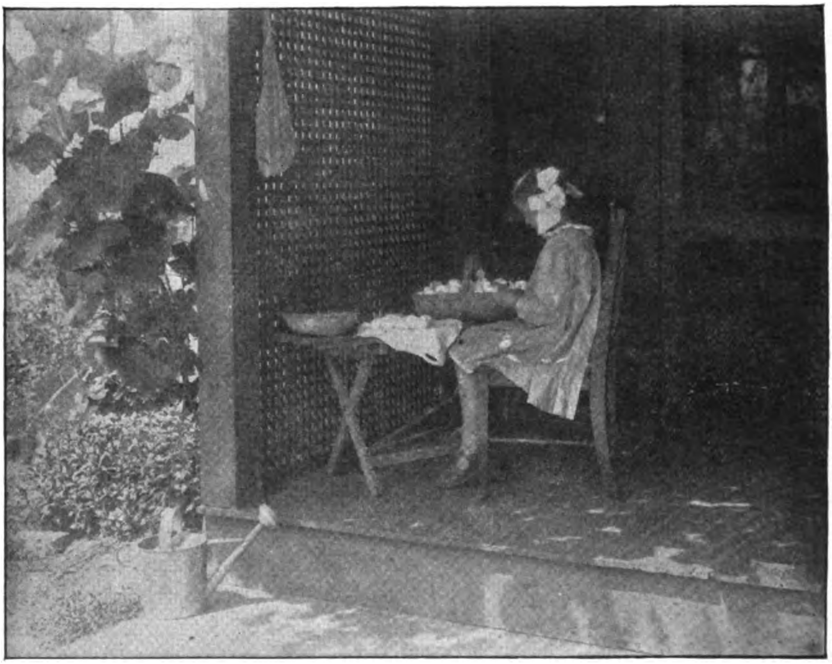

FIG. 14.—*Cleaning eggs on the farm. This work can often be done by the children. They will take a special pride in the quality of the poultry products*

colors are usually mixed together. A distinctly mixed odor of sulfur and sourness may usually be detected.

Black rot.— The last stage of the rot series is the black rot (Plate VI, sect. 16). In this stage the liquid contents of the egg appear to be very dark. The air cell is broken and there is a large amount of air in the egg, allowing the contents to shake about inside the shell. Very often the condition of the interior may be detected by the grayish appearance of the outside of the shell. When the egg is opened, a very distinct and offensive odor of sulfur is apparent. The yolk contents are of an oily

black color, usually with yellow particles of sulfur floating on the surface. The yolk contents are usually, but not necessarily, mixed with the albumen. The albumen is very watery, often being similar in appearance to sour whey. These eggs are useful only as fertilizer or for a few other possible commercial purposes.

ROUGH HANDLING

Many eggs become cracked, due to frequent frightening of the hens, poor nests, nests placed high from the floor, careless methods of handling and packing for shipment, and so forth.

Loose air cell

If an evaporated egg is roughly handled, as in shipment, the inner

FIG. 15.—*Holding eggs for shipment. If eggs cannot be held in an artificially cooled room, it is often desirable to sprinkle the floor in order to cool and moisten the air. The eggs must be kept from direct contact with the water, however, or they will become musty.* (*View in egg room, Department of Poultry Husbandry, Cornell University*)

membrane is sometimes ruptured, thus leaving the air as a free bubble in the albumen. Eggs of this class can be detected by candling. A special example is the No. 2 cold storage egg shown in Plate VI, section 11. Such eggs are not necessarily poor eggs, as is commonly supposed; they merely show the effect of evaporation and rough handling. After the membrane is ruptured, the eggs evaporate much more rapidly than before and the albumen becomes watery. Eggs of this kind should be used as soon as possible.

Check

If an egg is cracked after it leaves the body of the hen, and if the check in the shell is so slight as to allow no leaking of the egg contents, the egg

is termed a check (Plate I, sect. 7). A check in the shell provides an easy entrance for bacteria, and very often leads to excessive evaporation, stuck yolk, mold spots, and the series of rots. As soon as checked eggs are found, they should be removed from the others in order to avoid their leaking and soiling clean eggs and in order to avoid infection. They should be used as soon as possible.

Leaker

If a check in the shell is so open that the contents leak, the egg is termed a leaker.

Blind check

Sometimes a partly formed shell seems to become cracked while the egg is yet in the uterus. These fine cracks are then filled in with more shell, or at least with the gelatinous coating, before the egg is laid. The shell appears almost normal when the eggs are handled in ordinary light, but when held before the candler's light they appear as in Plate I, section 6. These eggs are very easily broken in transit, and if possible they should be separated and sold locally by the producer, thus avoiding breakage and an undesirable smearing of other eggs.

PRESERVATION

It is becoming more and more necessary for food products to be held over from the season of plenty to the season of scarcity. This may be done in large or small amounts. Eggs are particularly adapted to being held in small quantities by the housewife, or in large quantities by producers, dealers, institutions, and the like. During the past years many consumers have been prejudiced against every sort of egg that was not strictly fresh. The writer believes that this prejudice was aroused by the unjust uses made of the preserved products. For instance, in some localities the best grades of cold storage eggs have been sold as fresh, leaving only the poorer grades to be sold as cold storage. This action gives the wrong impression as to the quality of the average cold storage egg. This condition of affairs, however, is changing, and the processes of preserving eggs are coming to be of vital importance to every one concerned with the egg supply.

Home preservation

Many methods of home preservation have been tried, especially in recent years — that is, since about 1898. Some of these methods are: packing eggs in dry table salt, bran, oats, or sawdust; preserving them in dry wood ashes, powdered sulfur, powdered gypsum, salt brine, slaked lime and salt solution, sugar, limewater, or various solutions of water

glass; covering with vaseline, paraffin, patented preparations, butter, or lard. A few other methods have been tried experimentally, but they are too dangerous for ordinary use. These include preservation in potassium permanganate, in salicylic acid, in gum arabic and formalin, in gum arabic and salicylic acid; and dipping the eggs in sulfuric acid and sealing in glass jars. Of all these methods of preservation, the limewater and salt solution and the water-glass solutions seem to give the best results. Water glass usually gives the better results of the two, because of the chalky taste that can be detected in eggs preserved in the limewater and salt solution.

Limewater and salt solution.— The method of making this preservative is as follows: Slake four pounds of good quicklime in a small quantity of water; mix with four gallons of pure water; add two pounds of salt. Stir the mixture thoroughly several times, then allow it to settle. Pour off the clear liquid. The clear liquid is the part in which the eggs are to be preserved. There is about enough of this mixture when made by this rule to preserve thirty dozen eggs. The number, however, depends somewhat on the shape of the vessel used. This is one of the oldest methods employed, and is usually recommended as reliable.

Water-glass solution.— The water-glass preservative is prepared as follows: Mix one and one half quart of the commercial water-glass solution with eighteen quarts of pure water; water that has been boiled is preferable. Stir the mixture until the ingredients are thoroughly mixed. An earthen jar is the most suitable vessel for the mixture, although a tight odorless tub may be satisfactory. Two eight-gallon jars are sufficient for thirty dozen eggs, using the quantity of solution prescribed above. After the water glass is thoroughly mixed, pour it into the different vessels to be used, being sure that the vessels are absolutely clean. It is expected that in the near future a convenient form of water-glass powder will be on the market, thus avoiding the use of commercial solutions varying greatly in strength. If more water is needed in order to cover the eggs sufficiently, this may be safely added to the amount of five quarts of additional water to each one and one half quart of the original commercial water-glass solution used.

Eggs preserved by these methods have a relatively small air cell at the end of ten months (Plate VI, sect. 9). If the eggs have been kept in a cool place, the yolks appear well up in the albumen, and fresh, although slightly darker than the yolks of fresh eggs. The deposit of lime or water glass can usually be detected on the outside of the shells. When opened, one of these eggs usually possesses a characteristic pink albumen (Plate VII, sect. 29). The albumen is also very watery. The yolk is somewhat flattened because of the weakened vitelline membrane, and is also some-

what darkened in color. If the egg is infertile, the yolk is usually less changed in color than if the egg is fertile. Limed eggs possess a distinct chalky odor and flavor. If salt is added to the limewater as specified in the formula given above, this objectionable feature is largely avoided. Normal water-glass eggs possess practically no foreign odor or flavor. Eggs preserved by either of these methods are usually satisfactory for home use, but are difficult to handle on the market because of the ignorance of customers as to their desirability.

Cold storage

The practice of placing eggs in cold storage is being gradually perfected, so that it is coming to be a distinct economic benefit to both producers and consumers. The enormous investment necessary for the erection of a cold storage plant has tended to keep the business in the hands of capitalists. If the cold storage business is properly controlled, market conditions will be greatly improved by the presence of this industry in the field.

In order to properly hold eggs in cold storage, it is necessary that great care be given to uniformity of temperature, humidity, ventilation, condition of the eggs being put in storage, packages used, cleanliness of the rooms, and like factors. Because of this it is advisable for most persons to store their eggs in a large commercial storage house, rather than to endeavor to operate a small private plant.

No. 1 cold storage eggs.— A cold storage egg of the best quality, which has been properly handled and held in storage during a normal season of eight months at about 30° F., should appear to the candler as shown in Plate VI, section 10. The air cell is larger than that of the home-preserved egg, and the yolk appears slightly darkened. The boundary of the yolk is very distinct, due to the long holding at a low temperature. When opened, this best grade of cold storage egg appears as in Plate VII, section 30. The yolk stands up very round and full, and the albumen is fairly firm — much more so than in the home-preserved egg. The albumen has a slightly greenish tint, and the yolk is slightly darkened.

The cold storage egg appears much better than the home-preserved egg immediately after removal from the storage room or preservative. However, the storage egg deteriorates very rapidly after being removed from the low temperature, and soon becomes of about the same quality as the home-preserved egg. The fact that cold storage eggs can usually be boiled without cracking, and the greater transparency of the albumen, cause them to be much more popular on the general market than are home-preserved eggs. They are suitable for nearly all household uses. Due to the long holding and possible variations of temperature, humidity, ventilation, and the like, cold

storage eggs are particularly susceptible to molds, mustiness, foreign odors and flavors, and bacterial infection; therefore they must be carefully examined for these defects.

No. 2 cold storage eggs.— The lower grades of storage eggs appear as in Plate VI, section 11. Here the air cell is greatly enlarged, and the yolk is darkened and somewhat sunken in the albumen. If this egg is opened, it will be found to be very watery, the yolk flattened, and the albumen of a distinctly darkened tint. The vitelline membrane will be so weak that it will usually break as the egg is opened. These eggs are suitable for cooking purposes, and might well be used for this purpose by city persons of moderate means. The condition of this type of egg is caused either by poor storage methods or by the poor condition of the egg before it was put into storage.

Consumers might well make a practice of buying surplus eggs during the early spring months, when the eggs are of better quality, and preserving these eggs for use during November, December, and January. The total costs for cold storage, including transportation, storage charges, insurance, recandling, loss due to deterioration, and interest on investment, very seldom amount to more than five cents for a dozen eggs, if conditions of handling are correct.

Dried and frozen eggs

Cracked and broken eggs, as well as many of the other inferior grades, are being prepared as either a dried or a frozen product. These products are very satisfactory, especially for hotel or bakery use, where uniformity is an essential feature. The dried egg products are convenient for use in private families and camping parties, since they may be used satisfactorily for many purposes as substitutes for fresh eggs. Unless mixed with other substances, there is usually an objectionable sweet taste in the egg powder. One's appetite for egg products, however, could probably be cultivated if they were used habitually. These products are manufactured principally in the States of the Middle West, where many of the large egg packing-houses are located.

SUGGESTIONS TO PRODUCERS

1. Keep only strong, healthy breeders or layers, thus avoiding many inherited tendencies to produce inferior eggs.

2. Do not incubate any eggs of inferior market quality. The character may be inherited, as is the size, shape, and color of eggs.

3. Handle fertile eggs with special care, and keep all males separate from the flock except during the breeding season.

4. Feed the layers with proper rations. Avoid foods giving undesirable colors, flavors, or odors to the egg contents.

5. Supply plenty of lime for the formation of strong eggshells. This will avoid the probability of much contamination and breakage.

6. Have the houses well ventilated, thereby making them warmer in winter and cooler in summer. Thus the eggs will not be infected from filthy air, nor will they be chilled or heated readily.

7. Have the floors of houses, nests, dropping boards, and the surrounding ground, clean. If hens with filthy feet go to the nests, the eggs and the nests will be soiled.

8. Supply plenty of nests, and locate these so that the eggs will be evenly divided. Many eggs in one nest means excessive heating of the first eggs laid. Use nest eggs if necessary, in order to insure better distribution of the eggs. One nest to six hens is usually sufficient.

9. If any eggs are found in stolen nests, in the litter, or otherwise so that their age or condition is not absolutely known, candle such eggs before selling.

10. Gather the eggs regularly. Twice each day is advisable during excessively warm or excessively cold weather.

11. Separate all soiled eggs from the others at once, and use them at home if possible. If all the soiled eggs cannot be used at home, wipe them at once with a damp cloth. Avoid applying an excessive amount of moisture to the shells. If eggs are to go into cold storage, do not clean them.

12. Separate all checks and leakers, and use them at home or sell them separately.

13. Place eggs in a cool and rather moist, clean place as soon as gathered, and hold them there until sold.

14. Do not store eggs where they may absorb odors from other products.

15. Sell all eggs at least once each week. The time to sell should be adjusted to the market and to the conditions under which the eggs may be held.

16. Pack and handle eggs in such a way as to avoid as far as possible any unnecessary jarring, dust, and the like.

SUGGESTIONS TO DEALERS

1. Buy eggs on a quality basis; in other words, candle the eggs, and discriminate between good and poor ones. This will protect you, benefit the producer who takes care of his eggs, and encourage all producers to improve their products.

2. Show the producers the kind of eggs you need for your trade. They will undoubtedly try to produce them.

3. Remove all soiled and cracked eggs from the others as soon as received. These should be sold separately.

4. Do not keep eggs any longer than is necessary. Every day they are held injures their quality.

5. Keep eggs in a cool and rather moist place. If artificial refrigeration is available, a temperature of about 40° F. is desirable.

6. Do not store eggs with fruits or other products possessing distinct odors. The eggs may absorb these odors.

7. Avoid all unnecessary shaking and handling of eggs.

SUGGESTIONS TO CONSUMERS

1. Buy eggs from some responsible person or firm that guarantees their quality. This will insure a standardized product that can be depended upon for certain definite uses.

2. Do not buy more than a week's supply at one time, except when the eggs are to be held in cold storage or in water-glass solution, or otherwise preserved.

3. The very best grades of eggs are not necessary for all kitchen purposes; light floats, heavy floats, checks, eggs having small meat spots or small blood clots, cold storage eggs, water-glass eggs, limed eggs, and seven-day incubator infertiles, can probably be used satisfactorily for many purposes. All these eggs seem to be as healthful as the best grades.

4. Buy eggs in surplus quantities during March, April, and May, and place them in some preservative or in cold storage for use during the winter months, when fresh eggs are scarce and expensive.

5. Candle all eggs purchased, at least occasionally, in order to see how they grade. Return all poor eggs and learn the cause of their condition.

6. Provide a cool and rather moist, clean place for keeping eggs.

7. Keep eggs separate from any food products that possess distinct odors.

8. Break eggs into a separate dish before using.

9. If it is possible to be in touch with the producer of your egg supply, urge him to take better care of his flock and his eggs.

10. In many cases it is possible for consumers to have a flock of poultry of their own; they should make use of this opportunity.

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JANUARY, 1915 BULLETIN 354

CORNELL UNIVERSITY

AGRICULTURAL EXPERIMENT STATION OF

THE COLLEGE OF AGRICULTURE

Departments of Plant Pathology and Entomology

FURTHER EXPERIMENTS IN THE DUSTING AND SPRAYING OF APPLES

By DONALD REDDICK and C. R. CROSBY

ITHACA, NEW YORK
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CORNELL UNIVERSITY

AGRICULTURAL EXPERIMENT STATION

Experimenting Staff

The regular bulletins of the Station are sent free to persons residing in New York State who request them.

Ithaca, New York, November 30, 1914.

Director B. T. Galloway,

College of Agriculture,

Ithaca, New York.

Dear Sir:

We beg to submit herewith a report of work done under the Herman Frasch Industrial Fellowship, with the recommendation that it be published as Experiment Station Bulletin 354.

The work was performed during the summer of 1914 in the orchards of Fred H. Glidden & Son, Holley, New York, E. W. Catchpole & Sons, North Rose, New York, and O. W. Friedah, Owego, New York. The writers are particularly indebted to these men for their hearty cooperation in placing their orchards at our disposal and in liberally aiding the investigations in every way possible.

Valuable assistance in various technical details of the experiments has been given by Dr. Robert Matheson and M. D. Leonard, of the Department of Entomology, Dr. V. B. Stewart and H. D. Hendricks, of the Department of Plant Pathology, and S. C. Bishop. The materials used were kindly furnished by the Union Sulfur Company, New York City, and the Corona Chemical Company, Milwaukee, Wisconsin; the dusting machines were furnished by the Kansas City Dust Sprayer Manufacturing Company.

Respectfully submitted,

Donald Reddick,

Professor of Plant Pathology.

C. R. Crosby,

Professor of Entomology.

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FURTHER EXPERIMENTS IN THE DUSTING AND SPRAYING OF APPLES

DONALD REDDICK AND C. R. CROSBY

(*Received for publication November 30, 1914*)

INTRODUCTORY

The appearance of a bulletin from this station by F. M. Blodgett[1] has renewed the interest of apple growers in the possibility of applying fungicides and insecticides in the dry state for the control of certain diseases and insects of the orchard, the most notable of which are scab disease, codling moth, leaf roller, and green fruit-worm. It appears from Blodgett's work that an exceedingly finely ground sulfur applied in the dry state is a fairly satisfactory substitute for lime-sulfur solution in the control of apple scab, and that powdered arsenate of lead, in the quantities used, is more effective in the control of the various insects that chew than is the same material applied in suspension in water according to the general practice. The data show that dusting is a much more rapid process than spraying, but that the cost per tree is greater for the dry method than for the wet.

The rigid requirements of the new apple packing law[2] have awakened an unusual interest in more efficient methods of disease and insect control, and the apparent vagaries of the fungus causing apple scab have again brought forcibly to the attention of apple growers the fact that "they may make all the applications of spray usually recommended for the orchard and still have scabby fruit." The statement is fully verified in the records to be found later in this bulletin. Many growers realize that the time of application is all-important in scab control, and many make an effort to cover their trees with spray at critical times. Lack of equipment or of sufficient help often prevents this, the latter item being the more important factor. The young orchards that are rapidly coming into bearing add to the difficulty, and altogether orchard spraying makes a big addition to the seasonal labor load.

The basis on which renewed trials of dry mixtures have been made is fully detailed by Blodgett in the bulletin already referred to, which includes also a résumé of previous work along the same line. The work reported in the present bulletin is a direct continuation of that done by Doctor Blodgett, and his advice and criticism were available in the planning of the work.

[1] Blodgett, F. M. Experiments in the dusting and spraying of apples. Cornell Univ. Agr. Exp. Sta. Bul. 340: 149-179. 1914.

[2] New York State Apple Grading Law. Chapter 418 of the Laws of 1914.

OBJECTS OF THE PRESENT INVESTIGATION

The important points for determination seemed to be as follows:

1. Is the dust method practicable in very large old trees, such as are frequently found in New York orchards? In order to answer this pertinent inquiry, a Baldwin orchard, approximately fifty years of age, was selected for one of the experiments. In picking the fruit, it was necessary to use ladders thirty feet long in some of the trees.

2. Can the results obtained in 1913 be duplicated or improved in another season?

3. Can a mixture be used that contains a smaller percentage of lead arsenate as the insecticidal agent? The work of 1912 indicated that a mixture containing 10 per cent of lead arsenate is effective, and as this is the expensive ingredient in the mixture it is desirable to reduce the quantity used as much as possible.

4. Can the quantity of fungicide applied per tree be reduced? This might have been done directly by applying smaller quantities, but, since the next point also was involved, it was accomplished by adding diluents.

5. Can the adhesive properties of the dry mixture be improved by the addition of an inert substance? Three substances, which from preliminary tests gave promise of success, were tried. These were (1) hydrated lime, a substance commonly used in many previous experiments; (2) finely ground gypsum, which is of about the same commercial value as hydrated lime but which will not react with the oxidation products of sulfur; (3) a cheap grade of wheat flour. The glutinous nature of the flour seemed, in previous tests and when used in considerable quantity, to improve the adhesiveness of the mixture.

6. Is the fine sulfur applied in suspension in water an efficient fungicide? The use of a paste sulfur mixture employed by Blodgett did not give particularly promising results, but it was thought worth while to make another trial of a home-prepared paste, using the finely divided sulfur employed in the dust mixtures.

The experiments of the season, therefore, hinged about these six considerations.

Comparisons were made with a plat of trees treated with the standard treatment, lime-sulfur solution and arsenate of lead, and with a plat of trees that received no summer treatment. Details as to quantities of material used, dates of application and conditions influencing the same, time required, comparative costs, results, and methods of recording data, are given in connection with the individual experiments.

For experimental purposes small trees are desirable, but if dusting is to prove of greatest value it must be effective in the very large old trees so frequently found in many of our orchards. Accordingly a Baldwin orchard

approximately fifty years of age was selected for one of the experiments. In the other two cases, the highly susceptible variety Ben Davis was used. The orchards are widely separated geographically, thus overcoming local variations and making any results obtained of general application.

EXPERIMENTS IN THE GLIDDEN ORCHARD AT HOLLEY

The experimental orchard at Holley consisted of a block of Baldwin trees twenty rows wide and twelve rows long, with other trees of the same size and age on three sides, as shown in Fig. 16. The black lines separate the

B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	T
B	B	O	O	1	B	B	B	2	B	B	B	3	B	B	B	4	O	B	B	5	T
B	B	B	B	O	B	B	B	B	B	B	O	B	B	B	B	B	B	B	B	B	T
B	B	O	B	O	B	B	X	B	B	B	X	O	B	B	**B**^{3}	B	B	B	**B**^{3}	B	T
B	B	O	B	B	O	B	O	B	O	B	**B**^{3}	B	O	B	B	B	B	B	O	B	T
B	B	O	O	O	B	O	O	B	O	B	B	B	B	B	B	B	B	B	**B**^{2}	B	T
B	B	O	O	O	O	B	**B**^{3}	B	B	B	B	B	B	B	**B**^{2}	B	B	O	O	B	T
B	B	B	B	B	B	O	B	B	B	B	B	B	B	O	B	B	B	B	B	B	T
B	B	B	B	B	B	B	**B**^{2}	O	B	B	**B**^{2}	B	B	O	B	B	B	B	B	B	T
B	B	**B**^{3}	O	B	B	O	B	B	B	B	B	B	B	B	**B**^{1}	B	B	B	O	B	T
B	O	B	**B**^{1}	B	B	O	**B**^{1}	B	B	B	**B**^{1}	B	B	B	B	B	B	O	**B**^{1}	B	T
B	B	**B**^{2}	B	B	B	B	B	B	O	B	B	B	B	B	B	O	B	B	B	B	T
B	B	B	B	B	B	O	B	B	B	B	B	B	B	O	B	B	B	B	B	O	T

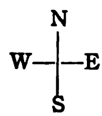


FIG. 16.— *Chart showing plan of experiments performed in the Glidden orchard, Holley, New York. The Baldwin trees (B) enclosed in the black lines represent the various plats, and the trees indicated by bold-faced type are the trees from which the apples were counted. The exponents refer to the order in which the data are presented in the table. B, Baldwin; T, Twenty Ounce; X, odd varieties; O, missing trees*

variously treated plats, and the letters set in bold-faced type indicate the trees from which counts were made. It was originally intended to count the yield from four trees, but this was found to be impracticable because of the amount of time and labor involved. The orchard seemed to be very uniform except for missing trees and a few odd varieties. In order to eliminate the personal equation, selection of count trees was made in June from a chart of the orchard. When a tree thus selected proved to be a poor and obviously unfair one or an odd variety, it was provided that the next tree beyond in the same row should be the count tree.

The block included an area of more than eight acres, with space for two hundred and forty trees set about forty feet apart each way. The land is nearly level, there being scarcely enough slope for drainage. This block is cultivated every other year. This year a sparse cover crop of clover was allowed to grow, but this was kept cropped close by sheep which were

allowed to run in the orchard. The trees are old, some of them are very large, and some need pruning badly. The orchard furnished an excellent opportunity for a test.

Methods and materials used

The solution used in the experiment in this orchard was applied with a power spraying outfit, carrying a pressure of 150 to 175 pounds, with two

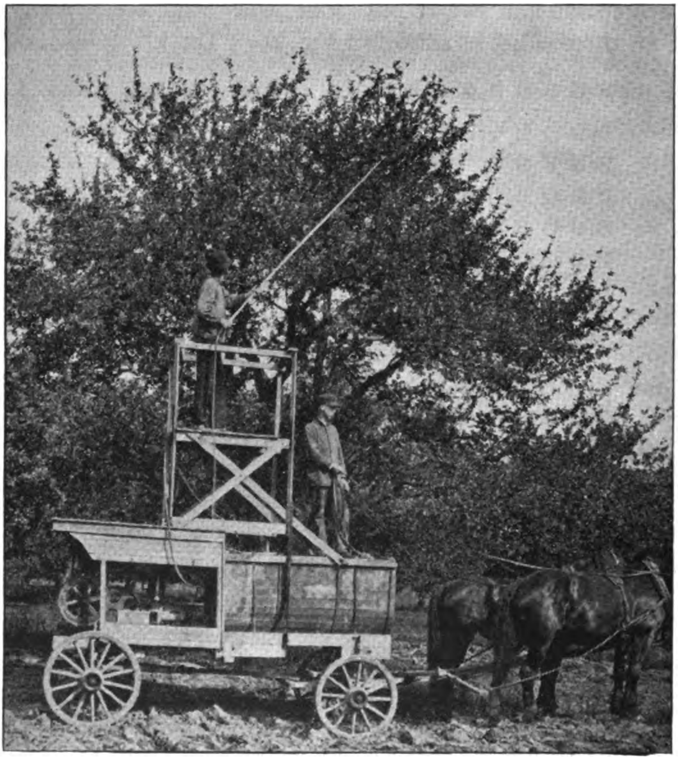


FIG. 17.—*Spraying outfit used in the Glidden orchard. Only one line of hose can be used profitably, due to the shape of the trees*

men and a team for its operation (Fig. 17). One line of hose was used and all the spraying was done from a tower. Considering the shape of the trees as shown in Figs. 18 and 19, this was a satisfactory method. It is the regular method employed by Mr. Glidden in forty acres or more of such trees.

The dust mixtures were applied with a large Ideal power outfit (Fig. 20), operated by a $2\frac{1}{2}$-horsepower horizontal New Way gasoline engine. An engine of this horsepower furnished abundance of power, whereas a $1\frac{1}{2}$-horsepower engine used by Blodgett did not seem to be large enough.

A dormant treatment of scale-strength lime-sulfur solution was applied to the entire block at a time when the first leaves were half grown. Three summer applications were made, the first at a time when the blossom buds still adhered in a cluster except in the tops of the trees. This was too early for pedicel protection from the scab fungus, but the various leaf-eating insects were abundant, and it was recalled that in 1913 the trees came into blossom in a very few days after the blossom buds reached the "cluster" stage. The second application was made when the blossoms had all fallen, and the third three weeks later. The first week in August one of the writers (R), in company with Mr. Glidden, examined the experimental block carefully and decided that there was no object in making a late application.

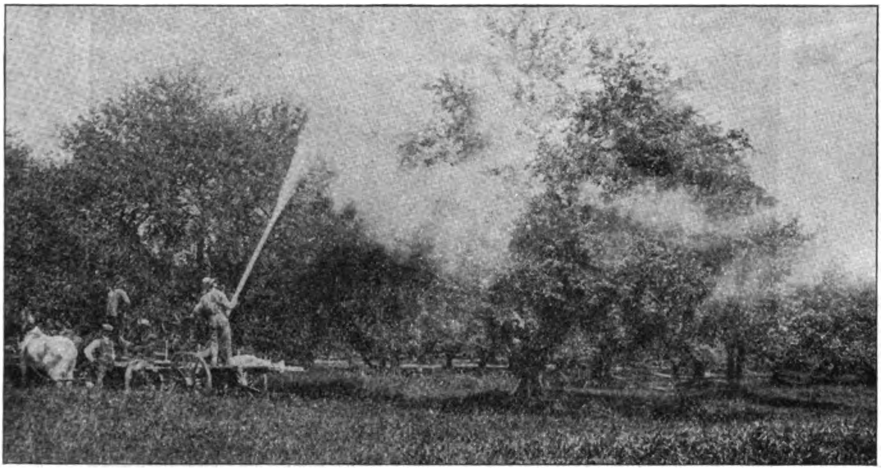


FIG. 18.—*Dusting in the Glidden orchard. The photograph shows the large size of the trees and the height to which the dust may be driven*

The fruit seemed to be unusually sound. How disastrously this resulted may be seen from a later table (Table 4).

In Table 1 are shown the dates, amounts of spray material used, and other data for the different applications. The cost figures are calculated on the basis of horse labor at 10 cents per hour, man labor at 20 cents per hour, lime-sulfur solution at 12 cents per gallon, dry arsenate of lead at 18 cents per pound, sulfur at $2.10 per hundred, ground gypsum at $8 per ton, and hydrated lime at $8 per ton. Obviously the figures are more or less arbitrary.[3] The cost of deterioration of the outfits is not taken into account, and the time lost in making adjustments of various sorts is not included in the record.

[3] Professor G. F. Warren, of the Department of Farm Management of this College, states that the cost of man labor here given is higher than the average and that of horse labor lower. Some of the prices of materials are based on large quantities and do not include freight charges. Since the figures are comparable in all cases, they are left in this form in order that they may be compared directly with the figures presented by Blodgett.

The relative cost per tree, also, is subject to considerable fluctuation. The dusting operations were not of sufficient duration to allow the operator to gauge accurately the quantity of material used per tree, as might be done in commercial work after a continuous run of half a day or even less. The time required per tree in spraying the experimental plat was greater than that required for treating trees of similar size and variety in the same orchard. On June 24 Mr. Glidden covered the same number of trees, of the same size, in one hour and fifty minutes. Since the same equipment was

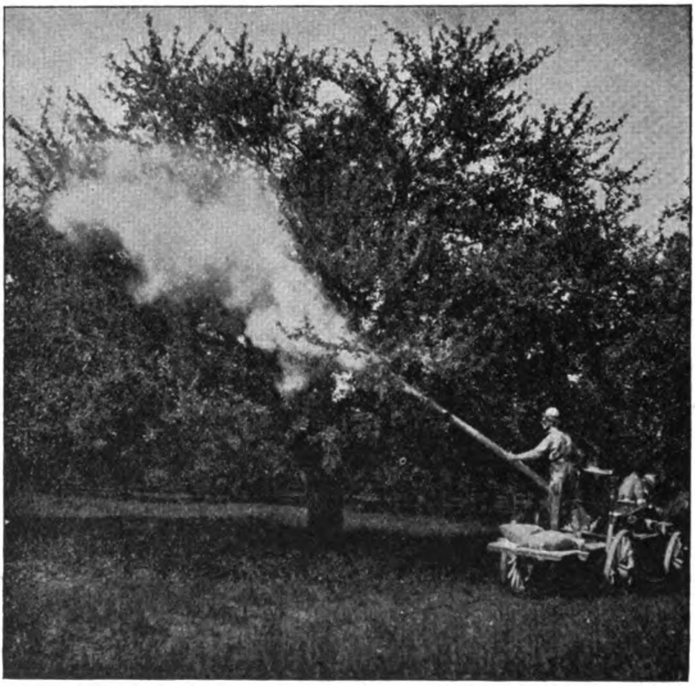


FIG. 19.—*Duster in operation in the Glidden orchard. The dust can be driven through trees with very dense foliage*

used, it is obvious that less material was used; and, other things being equal, the work must have been less effective, for no material was wasted, by dripping or otherwise, while the trees in the experimental plat were being treated. No allowance is made for time required in driving to and from the orchard, nor for filling the tank and mixing chemicals. For the entire orchard these operations may be estimated at thirty minutes for each tankful of mixture (200 gallons). Approximately this amount of time was required for the experiment, as the plats were somewhat less than halfway from the filling station to the most distant point in the orchard. It should be noted that, in dusting, enough material for a half day's work may be

TABLE 1. DATA ON TIME AND METHODS OF APPLICATION, GLIDDEN ORCHARD, HOLLEY, NEW YORK

Date of application	Plat	Number of trees	Material used, and strength	Quantity used	Time required						Cost			Cost per tree
					Horse		Man		Machine		Labor	Material	Total cost	
					Hrs.	Min.	Hrs.	Min.	Hrs.	Min.				
				(Lbs.)										
May 13	2	38	Sulfur 40, lead arsenate 10, hydrated lime 50	60	1	12	1	12	0	*36	$ .36	$ 1.70	$ 2.06	$.054
June 1	2	38		†140	1	20	1	20	0	40	.40	3.98	4.38	.115
June 18	2	38		160	‡1	32	1	32	0	46	.46	4.54	5.00	.131
Totals..	....	....	....	360	4	04	4	04	2	02	$1.22	$10.22	$11.44	$.300
May 13	3	43	Sulfur 80, lead arsenate 20	100	0	40	0	40	0	20	$ .20	$ 5.28	$ 5.48	$.127
June 1	3	43		160	1	18	1	18	0	39	.39	8.45	8.84	.205
June 18	3	43		195	1	28	1	28	0	44	.44	10.30	10.74	.250
Totals..	....	....	....	455	3	26	3	26	1	43	$1.03	$24.03	$25.06	$.582
May 13	5	41	Sulfur 40, lead arsenate 10, gypsum 50	80	0	42	...	42	0	21	$ .21	$ 2.27	$ 2.48	$.060
June 1	5	41		170	1	24	1	24	0	42	.42	4.83	5.25	.128
June 18	5	41		160	1	18	1	18	0	39	.39	4.54	4.93	.120
Totals..	......	....	....	410	3	24	3	24	1	42	$1.02	$11.64	$12.66	$.308
				(Gals.)										
May 14	4	43	Lime-sulfur solution (32°) 2.5 gallons, lead arsenate 3 pounds, water to make 100 gallons	375	6	00	6	00	3	00	$1.80	$ 3.83	$ 5.63	$.131
June 1	4	43		375	§6	00	6	00	3	00	1.80	3.83	5.63	.131
June 18 and 19	4	43		350	§6	00	6	00	3	00	1.80	3.57	5.37	.124
Totals..	....	....	....	1,100	18	00	18	00	9	00	$5.40	$11.23	$16.63	$.386

* Several stops of short duration, too short to be recorded satisfactorily, were made.
† The mixture seemed to flow much more freely than on May 13.
‡ A slower team was used, and the duster outlet was stopped down accordingly.
§ Estimated from careful record taken on time required to treat thirty trees.

carried easily with the outfit. The cost per tree of spraying, therefore, should be materially increased over the figures given in the table.

All applications were made from both sides of the trees. The wind did not prove a hindrance except when it came in gusts, and no attempt was made to apply the dust to the trees while they were wet with dew. The first application of dust was made during gentle rain, and the application on plat 2 (sulfur-lead-lime mixture) was followed by a heavy shower of several minutes duration. The sprayed plat (plat 4) did not receive the first treatment until the day following the application of dust, as the gentle rain continued into the night. Ordinarily this would have vitiated the experiment, but it is doubtful whether it did so in this case. Infection of the scab fungus occurred at this date only from fallen leaves. A number of spores were ejected during this rain period, but as there had been rain on the two previous days it is probable that all the mature spores had been ejected at least twenty-four hours prior to the time of making any of the applications, and the low temperature at the time doubtless retarded maturation of other spores.

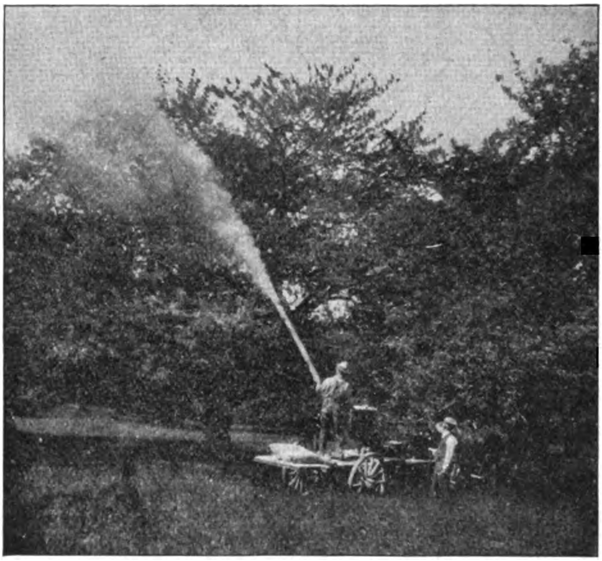


FIG. 20.—*Driving the dust to the top of a very large old Baldwin tree in the Glidden orchard*

It may be seen from the table that the cost of applying the dust mixtures is much less than for applying liquid, but that the dry materials are much more expensive. The cost of application of dust could doubtless be reduced somewhat below the figures given here. Later applications require a little more time than the first one, but in making the third application the duster was stopped down to half capacity because of a slowly moving team. The second application required more time because there was sufficient wind to make it uncertain that the cloud of dust directed at a certain part of the tree would actually reach it (Fig. 21). The machine, therefore, was moved at a rate which made it possible to redirect the flow toward that part of the tree if necessary.

It also appears from the table that the diluted dust mixtures were applied at approximately the same total cost per tree as was the solution. In reality the actual cost is lower, because of the fact that enough dry material may be carried along for a run of half a day, whereas in spraying much time is consumed in driving to and from the orchard and in filling the tank.

The relative quantities of the essential fungicidal and insecticidal ingredients applied per tree is of interest. According to Van Slyke, Bosworth, and Hedges (New York [Geneva] Agricultural Experiment Station, Bulletin

FIG. 21.—*Making an attempt to cover a branch missed the first time. The supply of material carried in bags should be noted also*

329, Table XI), a lime-sulfur concentrate testing 32° Beaumé contains 2.35 pounds of sulfur. Assuming that all the sulfur is liberated (which it is not), the sprayed trees in this orchard received at each application, on an average, 8.62 ounces of sulfur and 4.09 ounces of lead arsenate; trees in the plat dusted with 80-per-cent sulfur mixture received on an average 44.8 ounces of sulfur and 11.2 ounces of lead arsenate; those dusted with the mixture containing gypsum as a diluent received 21.3 ounces of sulfur and 5.33 ounces of lead arsenate; and those dusted with the mixture containing lime as a diluent received 20.16 ounces of sulfur and 5.04 ounces of lead arsenate.

TABLE 2. TRANSCRIPT OF RECORDS TAKEN AT THE ROCHESTER STATION OF THE WEATHER BUREAU OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

Date	Precipitation (inches)	Weather conditions
May 3	0	Partly cloudy
May 4	.02	Cloudy
May 5	.66	Cloudy
May 6	T*	Clear
May 7	.02	Partly cloudy
May 8	T	Cloudy
May 10	T	Cloudy
May 11	T	Cloudy
May 12	.68	Cloudy
May 13	.14	Cloudy
May 22	.05	Partly cloudy
May 23	0	Cloudy
May 24	0	Partly cloudy
May 25	.01	Partly cloudy
May 26	T	Partly cloudy
May 27	.16	Partly cloudy
May 29	T	Clear
May 30	.05	Clear
June 1	T	Clear
June 3	.03	Cloudy
June 4	.13	Cloudy
June 7	.28	Cloudy
June 8	0	Partly cloudy
June 13	0	Partly cloudy
June 15	T	Partly cloudy
June 16	.02	Clear
June 18	.25	Partly cloudy
June 19	.64	Cloudy
June 21	.08	Cloudy
June 22	.04	Cloudy
June 23	.03	Partly cloudy
June 24	T	Partly cloudy
June 26	T	Clear
June 27	.05	Cloudy
June 28	.08	Cloudy
June 29	.02	Cloudy
June 30	.06	Clear
July 1	.01	Cloudy
July 2	T	Cloudy
July 5	T	Clear
July 7	T	Cloudy
July 11	0	Partly cloudy
July 12	T	Partly cloudy
July 13	.01	Cloudy
July 14	T	Cloudy
July 16	.06	Partly cloudy
July 17	T	Cloudy
July 18	0	Partly cloudy
July 21	.08	Clear
July 23	.69	Cloudy
July 24	.02	Partly cloudy
July 25	.03	Clear
July 27	T	Cloudy

* Trace: an amount less than .01 inch, too small to be measured.

TABLE 2 (*continued*)

Date	Precipitation (inches)	Weather conditions
July 28	T	Partly cloudy
July 29	.01	Clear
July 31	0	Partly cloudy
August 1	0	Partly cloudy
August 2	.12	Partly cloudy
August 7	0	Partly cloudy
August 10	.59	Cloudy
August 11	.30	Cloudy
August 12	0	Partly cloudy
August 14	.21	Partly cloudy
August 16	.09	Partly cloudy
August 17	0	Partly cloudy
August 18	1.24	Cloudy
August 19	.02	Cloudy
August 20	.20	Cloudy
August 21	.46	Partly cloudy
August 23	.50	Cloudy
August 24	1.17	Cloudy
August 27	0	Partly cloudy
August 28	.12	Cloudy
August 29	.81	Cloudy
August 30	T	Partly cloudy
August 31	T	Partly cloudy

Diseases of the season

The only disease of any importance occurring in the orchard, amenable to the treatments given, was the scab disease (caused by *Venturia inaequalis*). Sooty blotch (caused by *Leptothyrium pomi*) was present to a limited extent in the untreated plat and on treated trees having very dense foliage.

Scab infection periods

It is a well-known fact that infections by the scab fungus are dependent on periods of rainfall, particularly when those periods are followed by foggy weather. Therefore a meteorological record of the season, properly interpreted, gives a general idea of the infection periods and their possible extent (Table 2). The season of 1914 was different from the preceding ones for a number of years, the first infection period (May 11, 12, and 13) coming before it was possible to make a first application to prevent pedicel infection. Considering that only the leaves of the blossom cluster had unfolded and that all infection was from the fallen leaves, the infection was unusually heavy. There ensued a dry period continuing through the blossoming period and extending through a sufficient time to allow making the calyx application on June 1. The dry period rendered useless the fungicide

applied the first time. At the date of the second application (June 1) the early infection showed abundantly on the under sides of the early leaves. These, of course, were largely leaves about the blossom cluster. No infections could be found on the pedicels of the young fruits, and none appeared subsequently. At the time when the second application was made, all the petals had dropped from the trees and the young apples were completely covered with a dense mat of fine hairs. This application afforded protection against infections occurring on June 3 and 4 and on June 7. These infections were much heavier than the first one, as spores (conidia)

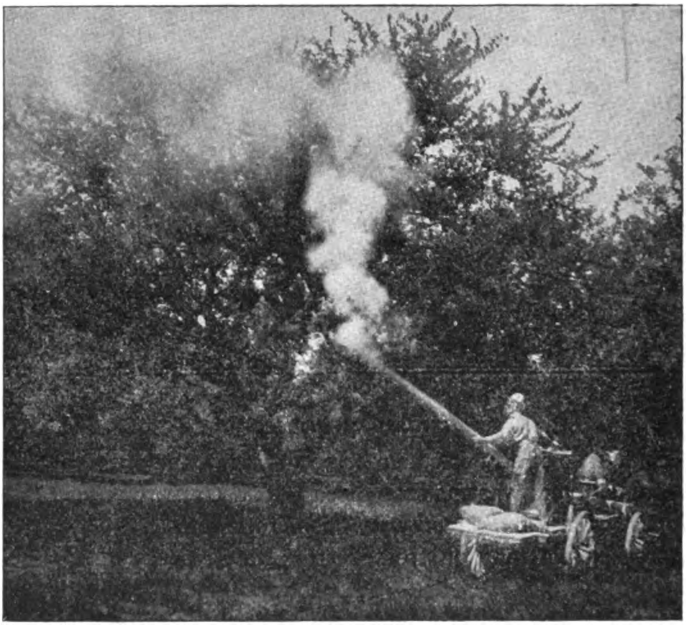


FIG. 22.—*Dusting in the Glidden orchard. The picture shows well the method of applying the dust by long vertical sweeps of the outlet tube*

were abundant on the infected leaves and spores (ascospores) were also shot from the fallen leaves in great abundance.

The third application was made on June 18. This application was most opportune, since it forestalled the largest infection of early summer.

The month of July was unusually dry (Table 2), and no further infection occurred in this orchard. As the amount of scab on the fruit seemed to be exceedingly slight and as there was no evidence of codling moth, the fourth application was omitted. August, however, proved to be a rainy month, and an unusually heavy late infection of scab occurred throughout the entire orchard.

Insects of the season

On May 12-13 Dr. R. Matheson visited the orchard and found that the bud moth was fairly abundant, 25 to 30 per cent of the buds on the branches near the ground being infested. The cigar case-bearer was also abundant, all the lower leaves being somewhat injured. On June 1 the orchard was again visited, by one of the writers (C). The apple leaf-roller was fairly abundant and the caterpillars were beginning to eat the stamens and the calyx lobes of the recently set apples. Only one fruit was seen that showed the characteristic feeding of the leaf roller at the side. A few green-fruit-worm caterpillars were observed at this time. Neither the first nor the second brood of codling moth was abundant, as is shown by the count of apples from the untreated plat.

The injury designated in Table 4 as "pinholes" should probably be attributed to several causes. These pinholes are slight blemishes, usually less than ⅛ inch in diameter, with a small hole at the center often partly filled with a whitish substance. The flesh of the fruit beneath the blemish has dried out and turned brownish to a depth of about ⅛ inch. Some of these spots may have been caused by codling-moth caterpillars that died after eating through the skin of the fruit, but the greater number were produced in some other way. It should be noted that in the Glidden orchard, where the apples are Baldwins, about 18 per cent of the fruits in the untreated plat were affected with pinholes, while at North Rose and at Owego the Ben Davis apples were not injured in this way.

Results of experiments

Apples that failed to set were caught in cheesecloth hammocks suspended under the count trees. None of these apples showed pedicel infection. An examination was made of the orchard on June 25. The infection of June 19 was not yet apparent. In order to confirm an impression that the infection from fallen leaves is greatest on the lower branches, as would be expected from the purely physical aspects of the case, a number of branches in the untreated plat were selected at random from the lower limbs and from limbs high in the tree. One thousand leaves were stripped from each lot of branches and the number of infected ones was determined. Of the lower leaves 39 per cent were infected, and of the upper leaves 30 per cent. No account is taken of the number of infections per leaf, and it should also be borne in mind that some of the infections were secondary. To be of most value, the count should have been made ten days earlier.

On July 10 all the drops from one of the count trees, and equal quantities from the other three, in each plat, were examined and graded into four classes: sound; scabby; attacked by leaf roller or green fruit-worm; attacked

by codling moth. The accompanying table (Table 3) shows the percentage of fruit for each class.

The table shows the expected reduction in amount of apple scab in the treated plats. It also indicates that the poisons were not effective against certain of the leaf-eating insects. It is chiefly valuable, however, in showing the practical freedom of the entire orchard from codling moth. The apples were picked and graded October 13 to 21. On October 11 a heavy wind caused a number of apples to fall. As it was thought these apples might show excessive injuries, they were graded separately. No such condition was found to exist, however, and these windfalls were counted in with the picked apples.

TABLE 3. CLASSIFICATION OF DROP APPLES ON JULY 10, 1914, GLIDDEN ORCHARD

Treatment	Total number of apples	Sound		Apple scab		Leaf roller and green fruit-worm		Codling moth	
		Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Untreated	488	337	69.06	95	19.47	69	14.14	1	.02
Lime-sulfur solution (32°) 2.5 gallons, lead arsenate 3 pounds, water to make 100 gallons	661	545	82.45	10	1.51	106	16.04	0	0
Sulfur 80, lead arsenate 20	387	307	79.33	18	4.65	62	16.02	0	0
Sulfur 40, lead arsenate 10, gypsum 50	2,071	1,828	88.27	30	1.45	211	10.19	2	.10
Sulfur 40, lead arsenate 10, hydrated lime 50	507	403	79.49	36	7.10	78	15.38	0	0

After two trees had been graded (Fig. 23), it became apparent that it would be physically impossible to count the apples from twenty trees. It was therefore decided to grade the fruit from only three trees in each plat, instead of from four as originally planned. The elimination of one count tree from each plat was left largely to chance. It depended chiefly on whether the tree had been picked or not, and in part on nearness to the last tree counted.

In making the tabulation the apples were first divided into sound and unsound. The unsound apples were further classified, each individual apple falling under one to six headings, depending on whether or not it was affected with scab from early infection or with scab from late infection; whether leaf roller and green fruit-worm had attacked it; whether or not codling moth and bud moth had attacked it in August; and whether the apples showed lesions which for want of a better name were designated as "pinholes."

No difficulty was experienced in separating the early-scab-infected apples from those affected late in the season. This separation is important, since the treatments given could not be expected to control the late infection. It should be noted, however, that late infection is very much greater on the untreated plat than on any of the others. This is attributable directly to better control of early scab. It was noted that in the treated plats apples bearing early scab spots were almost sure to show late infection also. The record of late infection is of considerable importance in the light of the new packing law. Technically a very large percentage (15 per cent or more) of these apples could not be sold in closed packages unless labeled, in thirty-six point Gothic letters, either "Fungused" or "Scabby."[4] Some of the scab spots were very small, and often there was only a single spot on an apple. There is some question as to whether such spots should exclude an apple from standard A or B grade, particularly in view of the fact that under modern cold storage no further damage should result. The words "practically free" as written in the law would certainly allow some of the apples graded as scabby to pass, but just where the line should be drawn seems to be an open question. As the apples from this orchard were sold "tree run," it was not necessary for the writers to settle this point.

FIG. 23.—*The number of apples per tree made it impracticable to classify the fruit from more than three trees in each plat*

A suitable method of recording the number of infections per apple is highly desirable, but there seems to be no practicable way of doing this when handling such large quantities of fruit. The result is that in the tabulation (Table 4) an apple wholly worthless from scab counts just the same as one bearing a small spot scarcely visible except when the light strikes from the proper angle.

[4] New York State Apple Grading Law. Chapter 418 of the Laws of 1914.

The relative value of the various materials used may be seen from Table 4. Percentages have been determined, and the mean of these percentages with the probable error[5] of the mean. This seems to be the method most frequently employed by biologists in statistical work of this kind. The method permits one to take into consideration the numerous factors that can be neither controlled nor calculated in such work. Some of the more important of these factors may be enumerated as follows, in their apparent order of importance: individuality of trees, particularly in their relative susceptibility; density of foliage and general shape of trees, in their relation more especially to fungous infection;

FIG. 24.—*Classifying the apples as they came from the trees. Each type of injury was recorded by means of a mechanical device*

failure to make uniform applications during the course of the experiment or during the preceding year. The error due to these factors can be considered as a casual one, and as such can be determined by calculating the probable error. This is a measure of the reliability of the experimental results, and means that the odds are equal that the true result lies somewhere within the data actually obtained ± the probable error.

Some persons dealing with statistics do not look on this method with favor, and in order to see what variations might occur the averages obtained by using totals have been determined. The writers are not in accord as to the more suitable method, and as it became increasingly apparent that the matter could not be settled a priori both sets of figures are presented here.

[5]The probable error as worked out is equal to $\pm\, 0.67 \sqrt{\frac{\Sigma d^2}{n(n-1)}}$

TABLE 4. CLASSIFICATION OF BALDWIN APPLES FROM THE GLIDDEN ORCHARD

Treatment	Total number of apples	Sound		Unsound		Apple scab				Leaf roller and green fruit-worm		Pinholes		Bud moth		Codling moth	
						Early		Late									
		Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Untreated	2,977	313	10.51	2,664	89.49	942	31.64	2,305	77.43	625	20.99	541	18.17	64	2.150	57	1.9147
	3,011	165	5.48	2,846	94.52	967	32.12	2,423	80.47	781	25.94	610	20.26	69	2.292	27	0.8967
	8,193	278	3.39	7,915	96.61	3,256	39.74	7,467	91.14	1,854	22.63	1,425	17.39	245	2.990	53	0.6467
Total	14,181	756		13,425		5,165		12,195		3,260		2,576		378		137	
Mean			**6.46**		**93.54**		**34.50**		**83.01**		**23.18**		**18.61**		**2.477**		**1.1528**
Probable error			±1.42		±1.42		±1.75		±2.79		±.98		±.58		±.016		±.26
Average			5.33		94.67		36.42		85.99		22.99		18.16		2.665		0.9661
Lime-sulfur solution (32°) 2.5 gallons, lead arsenate 3 pounds, water to make 100 gallons	6,260	4,438	70.89	1,822	29.11	380	6.07	696	11.12	619	9.89	432	6.90	226	3.610	14	0.2236
	5,509	2,964	53.80	2,545	46.20	507	9.20	1,099	19.95	1,052	19.10	533	9.68	214	3.885	17	0.3086
	4,122	2,684	65.11	1,438	34.89	234	5.68	663	16.08	501	12.15	397	9.63	116	2.814	0	......
Total	15,891	10,086		5,805		1,121		2,458		2,172		1,362		556		31	
Mean			**63.27**		**36.73**		**6.98**		**15.72**		**13.71**		**8.74**		**3.436**		**0.1774**
Probable error			±3.36		±3.36		±.74		±1.71		±1.86		±.61		±.099		±.0616
Average			63.47		36.53		7.05		15.47		13.67		8.57		3.499		0.1951
Sulfur 80, lead arsenate 20	3,630	2,416	66.56	1,214	33.44	139	3.83	579	15.95	343	9.45	263	7.25	125	3.444	22	0.6061
	3,257	2,514	77.19	743	22.81	131	4.02	331	10.16	212	6.51	149	4.58	54	1.657	7	0.2149
	3,186	2,175	68.27	1,011	31.73	116	3.64	518	16.26	302	9.48	234	7.34	51	1.600	2	0.0614
Total	10,073	7,105		2,968		386		1,428		857		646		230		31	
Mean			**70.67**		**29.33**		**3.83**		**14.12**		**8.48**		**6.39**		**2.234**		**0.2941**
Probable error			±2.20		±2.20		±.07		±1.33		±.66		±.61		±.41		±.109
Average			70.54		29.46		3.83		14.18		8.51		6.41		2.283		0.3078
Sulfur 40, lead arsenate 10, gypsum 50	4,761	3,449	72.44	1,312	27.56	79	1.66	462	9.70	321	6.74	411	8.63	164	3.445	0	......
	5,964	3,769	63.20	2,195	36.80	221	3.71	1,074	18.01	595	9.98	572	9.59	186	3.119	0	......
	6,665	4,220	63.32	2,445	36.68	421	6.32	1,143	17.15	479	7.19	742	11.13	169	2.536	2	0.0300
Total	17,390	11,438		5,952		721		2,679		1,395		1,725		519		2	
Mean			**66.32**		**33.68**		**3.90**		**14.95**		**7.97**		**9.78**		**3.033**		**0.0115**
Probable error			±2.05		±2.05		±.90		±1.76		±.68		±.49		±.178		±.0006
Average			65.77		34.23		4.15		15.41		8.02		9.92		2.984		0.0115
Sulfur 40, lead arsenate 10, hydrated lime 50	5,865	2,382	40.61	3,483	59.39	484	8.25	2,412	41.13	881	15.02	738	12.58	26	0.443	9	0.1535
	3,571	1,982	55.50	1,589	44.50	214	5.99	941	26.35	404	11.31	378	10.59	86	2.408	4	0.1120
	4,554	2,157	47.36	2,397	52.64	564	12.38	1,850	40.62	302	6.63	400	8.78	137	3.008	11	0.2415
Total	13,990	6,521		7,469		1,262		5,203		1,587		1,516		249		24	
Mean			**47.82**		**52.18**		**8.87**		**36.03**		**10.99**		**10.65**		**1.953**		**0.1690**
Probable error			±2.88		±2.88		±1.25		±3.24		±1.62		±.74		±.511		±.026
Average			46.61		53.39		9.02		37.19		11.34		10.84		1.780		0.1716

The greatest care has been taken to have the figures accurate. The records in the field were made on counting machines (Fig. 24). In making transcriptions all figures have been checked twice. All computations have been made by means of mechanical devices by one of the writers (R), and checked independently by M. D. Leonard and again in the editorial office at the College of Agriculture.

Scab control.— It is seen from the table that all the materials used gave very satisfactory control of early scab. Particular attention should be given to the variation of the individual trees in any one plat. In general, trees bearing a relatively small number of apples had less scab; trees on which the fruit was very highly colored seemed to have less scab, although not enough of this kind of trees were encountered to permit a generalization; apples from the north side of trees invariably had more scab. The greater abundance of scab on the north side of trees can be accounted for only by the fact that the very dense foliage allowed moisture to persist there longer after each shower, and thus allowed more infections to occur.

Blodgett[6] found that the use of lime as a diluent for sulfur in the control of hop mildew reduced the fungicidal value of the sulfur. It does not necessarily follow, however, that the same result would be obtained in the case of an organism the method of infection of which is different. It seemed possible, therefore, that the hydrated lime, which hardened on the foliage and adhered well, might not prove harmful in the control of apple scab. The heavy shower coming on this plat shortly after the first application vitiates the figures to a certain extent. This point will be discussed more fully in the general summary.

Insect control.—Codling moth injury was so slight, even in the untreated plat, that the figures given in the table have little significance. The data in regard to the control of August injury by bud-moth caterpillars are also of little value, because in order to be effective the application of the poison should have been made in the last week of July or early in August, soon after the hatching of the eggs.

It may be seen from the table that the pinhole injury, whatever its cause, was reduced from 18.16 per cent in the untreated plat to less than 11 per cent by the various treatments given. In considering the control of leaf roller, it should be remembered that in these experiments the applications were made much too late to be fully effective.

Sound and unsound fruit.— From the figures in Table 4 it may be seen that in total percentage of sound and unsound fruit there is no dependable difference between the various mixtures used except in the case when lime was used as a diluent. Whether this is due to the unfavorable

[6] Blodgett, F. M. Hop mildew. Cornell Univ. Agr. Exp. Sta. Bul. 328 : 298. 1913.

action of lime in the mixture, or to the heavy shower that came shortly after the first application was made, is uncertain. The other two dust mixtures seem to have been slightly superior to the lime-sulfur solution with lead arsenate, but the probable error is so large as to make this uncertain.

So far as this orchard is concerned, the first question to be determined (page 542) can be answered in the affirmative. The dust method is practicable in large trees. Based on the figures just presented, the second question can also be answered affirmatively. The result of 1913 has been somewhat improved upon, in that a higher percentage of sound apples has been secured with a similarly low percentage of sound fruit on the untreated plat.

EXPERIMENTS IN THE CATCHPOLE ORCHARD AT NORTH ROSE

The trees used for experimental purposes this year in the Catchpole orchard are located only a short distance from those used last year by Doctor Blodgett. They are of the variety Ben Davis, a variety particularly susceptible to scab. The trees are twenty years of age, are set 33 by 33 feet, and are very uniform in size and shape. The system of pruning employed is that of very light annual pruning. The trees are very dense and the lower branches reach to the ground (Fig. 25). Repeated and thorough spraying is practiced annually. The soil is a sandy loam and the ground is practically level. The orchard is fertilized, cover-cropped, and thoroughly cultivated between the rows each year. The system of pruning prevents cultivation directly under the trees. Fallen leaves of the previous year persist under the trees, and when scabby they form a hotbed of infection. This was the case in 1914.

It will be seen from the plan of the experiment (Fig. 26) that the plats are bordered on three sides by trees of the same size and age. The count trees here (indicated by bold-faced type), as elsewhere, were predetermined from a chart of the orchard.

Methods and materials used

The solution used on the sprayed plat was applied with a large power sprayer, with a pressure of 150 pounds or more and with three men and a team for its operation (Fig. 25). The dusting machine was like the one used in the Glidden orchard. It was driven by a 2½-horsepower horizontal New Way engine, which furnished ample power and was a great improvement over the equipment of the previous year.

Particular mention should be made of the thorough manner in which the trees were sprayed. It will be seen from Table 5 that more than

five gallons of spray was applied per tree at each application. This was accomplished by driving completely around each tree, thus covering all parts thoroughly.

All applications of the dust mixtures were made from both sides of the trees. The first application was made on a calm day and the work was done very quickly. At the time of the second application there was

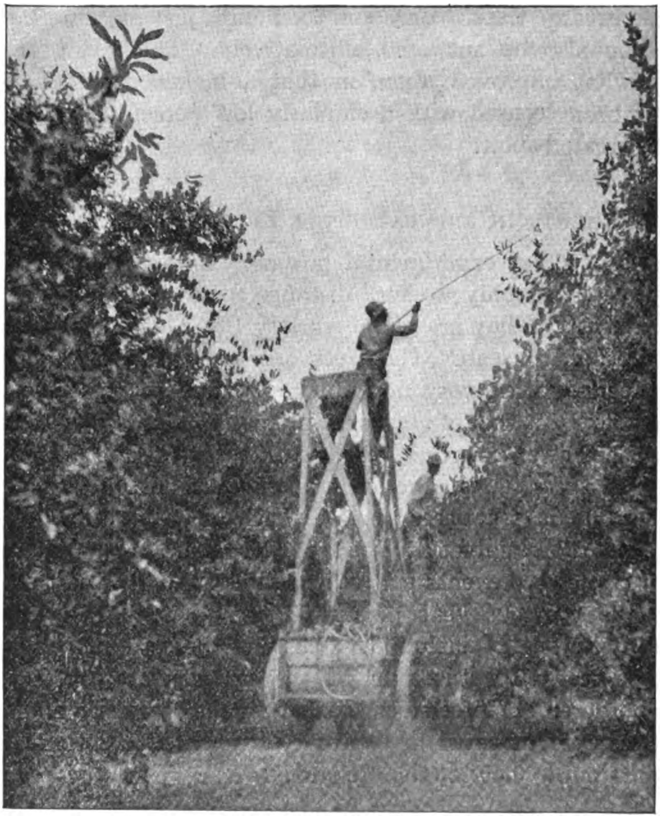


FIG. 25.—*Spraying in the Catchpole orchard. The photograph shows well the size and shape of the trees in this orchard*

a high wind, which came in sharp gusts and made impossible a thorough application of dust. There was also more wind at the time of the third and fourth applications than is desirable for dusting. A dormant treatment of scalecide was applied to the entire block. Four summer applications were made. At the time of the first application (May 15) the clusters of buds were beginning to separate and show pink, but many

were not far enough along to permit driving the fungicide to the pedicels of the innermost blossoms. The second application was made on May 30, at a time when all the petals had fallen. The third application was made on June 19 and was gauged rather for codling moth than for scab. The fourth application was made on August 7, largely to forestall a possible late infection of scab. Each time the treatment of the various plats was made in the forenoon of the same day.

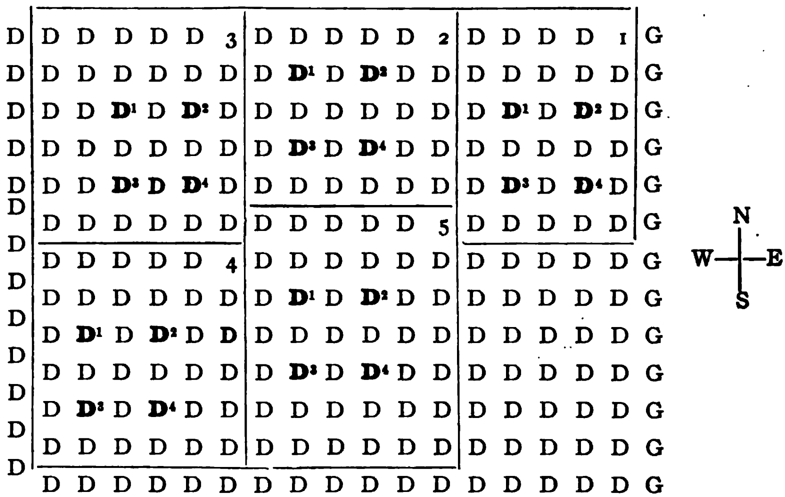


FIG. 26.— *Chart showing plan of experiment performed in the Catchpole orchard, North Rose, New York. The Ben Davis trees (D) enclosed in the black lines represent the various plats, and the trees indicated by bold-faced type are the trees from which the apples were counted. The exponents refer to the order in which the data are presented in the tables. D, Ben Davis; G, Greening*

By mistake the trees in plat 1 (dusted with sulfur, lead arsenate, and hydrated lime) received an application of bordeaux mixture, from one side only, on May 14, the day previous to the first application of the dust mixture. As this was applied too late to prevent the primary infection, and as no other infections occurred until after the blossoms were off, presumably it did not interfere in any way with the experiment.

Details of the dates of application, materials used, time required, cost data, and so forth, are shown in Table 5. The cost figures are calculated on the same basis as in the Glidden orchard. The cost of deterioration of outfits, interest on investment, and so forth, are not considered, and the time lost in making adjustments is not included in the records.

TABLE 5. DATA ON TIME AND METHODS OF APPLICATION, CATCHPOLE ORCHARD, NORTH ROSE, NEW YORK

Date of application	Plat	Number of trees	Material used, and strength	Quantity used	Time required						Cost			‡Cost per tree
					Horse		Man		Machine		Labor	Material	Total cost	
					Hrs.	Min.	Hrs.	Min.	Hrs.	Min.				
				(Lbs.)										
May 15*	1	30	Sulfur 40, lead arsenate 10, hydrated lime 50	70	0	26	0	26	0	13	$.13	$1.99	$2.12	$.071
May 30	1	30		80	0	†50	0	50	0	25	.25	2.27	2.52	.084
June 19	1	30		95	0	42	0	42	0	21	.21	2.70	2.91	.097
Totals..	....	....	....	245	1	58	1	58	0	59	$.59	$6.96	$7.55	$.252
May 15	3	36	Sulfur 80, lead arsenate 20	70	0	30	0	30	0	15	$.15	$ 3.70	$ 3.85	$.107
May 30	3	36		90	0	56	0	56	0	28	.28	4.75	5.03	.140
June 19	3	36		130	0	48	0	48	0	24	.24	6.86	7.10	.197
Totals..	....	....	....	290	2	14	2	14	1	07	$.67	$15.31	$15.98	$.444
May 15	4	36	Sulfur 40, lead arsenate 10, gypsum 50	70	0	27	0	27	0	13	$.13	$1.99	$2.12	$.059
May 30	4	36		100	0	56	0	56	0	28	.28	2.84	3.12	.087
June 19	4	36		90	0	40	0	40	0	20	.20	2.56	2.76	.077
Totals	....	....	....	260	2	03	2	03	1	01	$.61	$7.39	$8.00	$.223
				(Gals.)										
May 15	5	42	Lime-sulfur solution (32°) 2.5 gallons, lead arsenate 2.5 pounds, water to make 100 gallons	§225	1	40	2	30	0	50	$ .67	$1.69	$2.36	$.056
May 30	5	42		225	1	40	2	30	0	50	.67	1.69	2.36	.056
June 19	5	42		225	1	40	2	30	0	50	.67	1.69	2.36	.056
Totals	....	....	....	675	5	00	7	30	2	30	$2.01	$5.07	$7.08	$.168

* By mistake trees in this plat were treated on May 14, from one side only, with bordeaux mixture 3-3-50 and powdered arsenate of lead (30%) 1½-50.
† It was necessary to stop at each tree because of the high wind.
‡ No record was made of time or material used in late application. Approximately one third more may be added to this figure.
§ The quantity applied per tree is greater than was used by the owner on adjacent trees of the same age.

Owing to the very efficient methods of spraying employed in this orchard (Figs. 25 and 27), the time required for covering a tree thoroughly is not so long as in most orchards. The result is that the cost per tree for spraying appears to be less than for dusting. When the time required for driving to and from the orchard and for filling the tank is counted in, it is probable that the total cost per tree for spraying would about equal the total cost per tree for dusting with the diluted mixture. No accurate data are available on the time element involved, and the three records made under the conditions of the experiment are of little value in determining the average. Through an oversight records were not kept at the time of the fourth application. To determine the total cost per tree for the season, approximately one third more should be added to the cost indicated in the table.

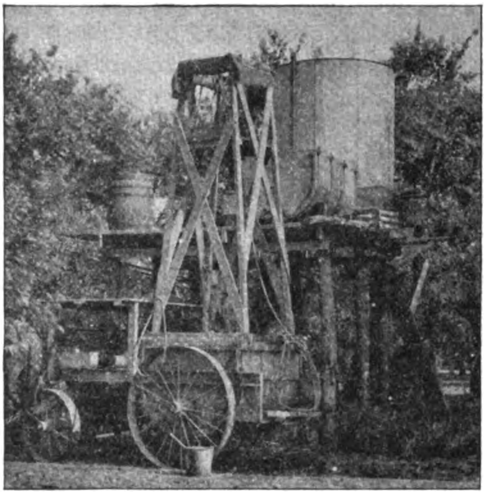


FIG. 27.—*Filling station in the Catchpole orchard. The convenient arrangement of this filling station makes it possible to load and get away in seven minutes. It helps to reduce the cost of spraying, but, what is more important, it helps to keep the sprayer working at maximum capacity*

The average relative quantities of essential fungicidal and insecticidal ingredients applied per tree each time are as follows: sprayed plat, sulfur 5.42 ounces, lead arsenate 2.57 ounces; plat dusted with 80-per-cent sulfur mixture, sulfur 34.30 ounces, lead arsenate 8.58 ounces; plat dusted with mixture containing gypsum as a diluent, sulfur 15.36 ounces, lead arsenate 3.84 ounces; plat dusted with mixture containing lime as a diluent, sulfur 17.41 ounces, lead arsenate 4.35 ounces.

Diseases of the season

The only disease occurring in this orchard amenable to the treatments given was scab. Here, as in the Glidden orchard, the first infection occurred May 11, 12, and 13. The fallen leaves of the previous year formed a dense mat under the trees and bore abundant fruiting bodies of the scab fungus, some of which likewise were mature earlier than usual.

Scab infection periods

At the time of the second application in this orchard, May 30, the infections of May 11, 12, and 13 were showing abundantly on the under

sides of the leaves about the blossom cluster. There was rain during the night of May 28 and a light shower at six o'clock on the morning of May 30. As these rains were followed by high wind and clearing weather, the amount of infection occurring was not very great. It was sufficient, however, to furnish an abundant supply of fresh spores for the most important infection period of the season. By reference to the Rochester weather record (Table 2) it may be seen that infection weather occurred on June 3 and 4, and on June 7. The rain recorded for Rochester on June 18 did not occur at North Rose. The third application was made in the forenoon of June 19, and at three o'clock in the afternoon of the same day rain set in which developed into a drenching torrent. The solution applied had had time to partially set on the trees, but it is quite probable that the dust mixtures were washed off as there had been no opportunity for dew or any other agency to assist in bringing about better adherence.

It seems likely that much infection took place during the night of June 19, and that much more occurred on June 21, 22, 23, and 24 — a most excellent period for infection, with just enough rain to keep the foliage wet and enough cloudiness to prevent too rapid drying-out of the drops. There was little additional infection weather during the summer, until the mid-August period. At that time abundant late infection occurred.

Insects of the season

The Catchpole orchard was singularly free from injurious insects subject to control by the treatments. Only a small number of leaf-roller and green-fruit-worm caterpillars were present. Neither codling moth nor bud moth was abundant. The pinhole injury, so prevalent in the Glidden orchard, was not present here.

Results of experiments

As in the Glidden orchard, pedicel infection by the scab fungus did not occur. This may be attributed directly to the dry period during the latter half of May. An examination of the orchard was made on June 27. It was evident that the infections occurring during the night previous to the second application (the night of May 29) were of considerable extent. These spots showed both on the older leaves from leaf buds and on the young fruits.

On July 7 additional infections from June 19 and June 21, 22, 23, and 24 were coming into evidence. The drop apples were picked up on this date from under the count trees, and were examined and classified. The classification is shown in Table 6:

TABLE 6. CLASSIFICATION OF DROP APPLES PICKED UP ON JULY 7, 1914, CATCHPOLE ORCHARD

Treatment	Total number of apples	Sound		Apple scab		Leaf roller and green fruit-worm	
		Number	Percentage	Number	Percentage	Number	Percentage
Untreated	230	58	25.22	162	70.43	12	5.22
Lime-sulfur solution (32°) 2.5 gallons, lead arsenate 3 pounds, water to make 100 gallons	414	321	77.54	87	21.01	6	1.45
Sulfur 80, lead arsenate 20	324	190	58.64	134	41.36	0	0
Sulfur 40, lead arsenate 10, gypsum 50	329	96	29.18	228	69.30	12	3.65
Sulfur 40, lead arsenate 10, hydrated lime 50	236	140	59.32	84	35.59	12	5.08

A decided reduction in scab is indicated for the sprayed plat, and the averages for the various plats will be found to agree fairly closely with later classifications from the same trees.

On August 7 the trees in the entire orchard were thinned. The men who did this work were instructed to remove unsound fruit whenever there was a preference. The classification (Table 7) of these apples, therefore, should be held in mind in interpreting the table given later for picked apples.

The relative value of the various materials used may be seen from Table 8. The computations have been made with the same care as for the Glidden orchard. In this orchard, where the yield per tree was four to six barrels, it was possible to classify the fruit from all four count trees. This increases the probability that the figures given represent a true mean for the various plats. If one thousand apples could have been taken at random from each of ten trees, the actual labor would not have been increased and a more reliable mean could have been secured. Under the system of picking employed, however, this could not be done because of the difficulty of securing random samples, and this in turn was due to the fact that lower branches bore more scabby fruit than did those in the tops of the trees and apples on the north side of trees were more scabby than those on the south side.

Scab control.— The table shows a very high percentage of early summer infection on untreated trees, which can be attributed to the large amount of infection material under the trees, to the fact that a severe primary infection occurred before a protective coating could be applied, and to the prolonged period of infection weather — June 21, 22, 23, and 24. The late infections were very abundant also. Almost invariably apples showing early infection also showed the late attack, and in addition

TABLE 7. CLASSIFICATION OF BEN DAVIS APPLES REMOVED FROM THE TREES ON AUGUST 7, 1914, CATCHPOLE ORCHARD

Treatment	Total number of apples	Sound		Unsound		Apple-scab		Leaf roller and green fruit-worm		Codling moth		Curculio	
		Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Untreated	1,530	36	2.35	1,494	97.65	1,390	90.85	95	6.209	7	0.4575	0	
	1,377	37	2.69	1,340	97.31	1,150	83.51	100	7.262	5	0.3631	0	
	1,497	43	2.87	1,454	97.13	1,330	88.84	160	10.688	4	0.2672	0	
	1,305	192	14.71	1,113	85.29	990	75.86	130	9.962	3	0.2299	0	
Total	5,709	308		5,401		4,860		485		19			
Mean			5.66		94.34		84.76		8.530		0.3294		
Probable error			±2.02		±2.02		±2.24		±.71		±.034		
Average			5.40		94.60		85.13		8.495		0.3328		
Lime-sulfur solution (32°) 2.5 gallons, lead arsenate 3 pounds, water to make 100 gallons	1,412	771	54.60	641	45.40	560	39.66	75	5.312	0		23	1.629
	1,202	667	55.49	535	44.51	470	39.10	77	6.406	0		16	1.331
	586	470	80.20	116	19.80	87	14.85	20	3.413	0		6	1.024
	1,530	750	49.02	780	50.98	665	43.46	174	11.373	0		37	2.418
Total	4,730	2,658		2,072		1,782		346				82	
Mean			59.83		40.17		34.27		6.626				1.601
Probable error			±4.65		±4.65		±4.38		±1.14				±.22
Average			56.19		43.81		37.67		7.315				1.734
Sulfur 80, lead arsenate 20	1,259	393	31.22	866	68.78	805	63.94	82	6.513	0		0	
	1,023	407	39.78	616	60.22	578	56.50	55	5.376	6	0.5865	0	
	1,513	389	25.71	1,124	74.29	985	65.10	110	7.270	4	0.2644	0	
	1,060	335	31.60	725	68.40	565	53.30	58	5.472	6	0.5660	0	
Total	4,855	1,524		3,331		2,933		305		16			
Mean			32.08		67.92		59.71		6,158		0.3542		
Probable error			±1.94		±1.94		±1.92		±.302		±.093		
Average			31.39		68.61		60.41		6.282		0.3296		
Sulfur 40, lead arsenate 10, gypsum 50	2,061	173	8.39	1,888	91.61	1,780	86.37	109	5.288	0		6	0.2911
	1,362	66	4.85	1,296	95.15	1,260	92.51	86	6.314	0		5	0.3671
	2,049	100	4.88	1,949	95.12	1,835	89.56	234	11.420	0		0	
	2,302	176	7.65	2,126	92.35	1,990	86.45	128	5.560	0		47	2.0417
Total	7,774	515		7,259		6,865		557				58	
Mean			6.44		93.56		88.72		7.145				0.6750
Probable error			±.62		±.62		±.98		±.965				±.310
Average			6.62		93.38		88.31		7.165				0.7461
Sulfur 40, lead arsenate 10, hydrated lime 50	547	100	18.28	447	81.72	325	59.41	102	18.647	4	0.7313	6	1.0969
	834	259	31.06	575	68.94	485	58.15	132	15.827	13	1.5587	7	0.8393
	1,325	295	22.26	1,030	77.74	910	68.68	191	14.415	9	0.6792	17	1.2830
	1,359	213	15.67	1,146	84.33	960	70.64	245	18.028	7	0.5151	26	1.9132
Total	4,065	867		3,198		2,680		670		33		56	
Mean			21.82		78.18		64.22		16.729		0.8711		1.2831
Probable error			±2.26		±2.26		±2.13		±.657		±.016		±.015
Average			21.33		78.67		65.93		16.482		0.8118		1.3776

TABLE 8. CLASSIFICATION OF PICKED BEN DAVIS APPLES FROM THE CATCHPOLE ORCHARD

Treatment	Total number of apples	Sound		Unsound		Apple scab				Leaf roller and green fruit-worm		Bud moth		Codling moth	
						Early		Late							
		Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Untreated	3,118	270	8.66	2,848	91.34	2,191	70.27	2,461	78.93	65	2.085	47	1.5074	*19	0.6094
	2,793	150	5.37	2,643	94.63	2,100	75.19	2,466	88.29	38	1.361	25	0.8951	0	
	2,837	540	19.03	2,297	80.97	1,453	51.22	1,978	69.72	68	2.397	11	0.3877	0	
	2,889	156	5.40	2,733	94.60	2,111	73.07	2,562	88.68	63	2.181	14	0.4846	0	
Total	11,637	1,116		10,521		7,855		9,467		234		97		19	
Mean			9.62		90.38		67.44		81.41		2.006		0.8187		0.1523
Probable error			±2.16		±2.16		±3.68		±3.02		±.15		±.17		±.10
Average			9.59		90.41		67.50		81.35		2.011		0.8335		0.1633
Lime-sulfur solution (32°) 2.5 gallons, lead arsenate 3 pounds, water to make 100 gallons	2,789	1,938	69.49	851	30.51	554	19.86	579	20.76	52	1.864	8	0.2868	0	
	2,229	1,401	62.85	828	37.15	542	24.32	506	22.70	99	4.441	6	0.2691	0	
	2,760	1,771	64.17	989	35.83	204	7.39	287	10.40	79	2.862	5	0.1812	0	
	3,147	1,839	58.44	1,308	41.56	802	25.48	840	25.69	181	5.752	16	0.5084	1	0.0318
Total	10,925	6,949		3,976		2,102		2,212		411		35		1	
Mean			63.74		36.26		19.26		20.14		3.730		0.3114		0.0079
Probable error			±1.52		±1.52		±2.77		±2.32		±.58		±.11		±.027
Average			63.61		36.39		19.24		20.25		3.762		0.3204		0.0092
Sulfur 80, lead arsenate 20	2,812	761	27.06	2,051	72.94	1,429	50.82	1,383	49.18	49	1.743	43	1.5292	14	0.4979
	2,022	757	37.44	1,265	62.56	828	40.95	831	41.10	80	3.956	12	0.5935	1	0.0494
	2,673	846	31.65	1,827	68.35	1,018	38.08	1,269	47.47	141	5.275	8	0.2993	0	
	3,042	769	25.28	2,273	74.72	1,321	43.43	1,697	55.79	130	4.274	14	0.4602	0	
Total	10,549	3,133		7,416		4,596		5,180		400		77		15	
Mean			30.36		69.64		43.32		48.38		3.812		0.7206		0.1368
Probable error			±1.82		±1.82		±1.83		±2.02		±.500		±.186		±.081
Average			29.70		70.30		43.57		49.10		3.792		0.7299		0.1422
Sulfur 40, lead arsenate 10, gypsum 50	1,969	230	11.68	1,739	88.32	1,228	62.37	1,358	68.97	226	11.478	9	0.4571	1	0.0508
	2,082	290	13.93	1,792	86.07	1,444	69.36	1,206	57.93	239	11.479	29	1.3929	0	
	†1,470	153	10.41	1,317	89.59	996	67.76	1,226	83.40	104	7.075	3	0.2041	0	
	3,179	357	11.23	2,822	88.77	2,139	67.29	2,594	81.60	337	10.601	9	0.2831	17	0.5347
Total	8,700	1,030		7,670		5,807		6,384		906		50		18	
Mean			11.81		88.19		66.69		72.97		10.158		0.5843		0.1464
Probable error			±.50		±.50		±1.01		±3.91		±.704		±.175		±.086
Average			11.84		88.16		66.75		73.38		10.414		0.5734		0.2068
Sulfur 40, lead arsenate 10, hydrated lime 50	3,530	1,330	37.68	2,200	62.32	1,669	47.28	1,686	47.76	85	2.408	20	0.5666	0	
	2,832	1,248	44.07	1,584	55.93	965	34.07	1,231	43.47	47	1.660	25	0.8828	0	
	3,109	1,058	34.03	2,051	65.97	1,590	51.14	1,670	53.72	61	1.962	12	0.3860	0	
	3,170	1,482	46.75	1,688	53.25	1,290	40.69	1,346	42.46	57	1.798	28	0.8833	0	
Total	12,641	5,118		7,523		5,514		5,933		250		85			
Mean			40.63		59.37		43.29		46.85		1.957		0.6797		
Probable error			±1.96		±1.96		±2.52		±1.72		±.108		±.062		
Average			40.49		59.51		43.62		46.93		1.978		0.6724		

* Calyx entrance.

† Nine bushels. Ten bushels more from this tree were not recorded.

many others were infected. The control of both early and late scab is decidedly better on the sprayed plat than on any of the dusted ones, but even so the percentage of control is not very satisfactory. Judging from the fact that certain other parts of the Ben Davis orchard were said by the pickers to have been freer from scab than the experimental plats, it would appear, since those trees were sprayed some days earlier than the ones in the experiment, that the drenching rain came before the material had set properly. Unfortunately unpicked trees from such parts of the orchard could not be found for making a count to verify the impression of the pickers.

The dust mixtures were more completely removed from the trees by this torrent of rain, which occurred on the afternoon of the day when the applications were made, than was the solution; and thus the trees were only partially protected from the infections following on June 21 and continuing for four days.

Insect control.— The codling moth was too scarce in this orchard to make the experiments of any value in regard to its control. The bud moth was not abundant in the spring, and the count of the apples showed that the next generation, in late summer, was not numerous. Apparently enough of the poison was effective to slightly reduce the number of apples injured by bud-moth caterpillars in August.

EXPERIMENTS IN THE FRIEDAH ORCHARD AT OWEGO

The experimental orchard at Owego consisted of a block of two hundred and eighty-six Ben Davis trees, twenty-one years of age (Fig. 28). The trees are in the same orchard as was used by Blodgett in 1913 under the name of Lawson orchard. The orchard has not been cultivated or pruned in a number of years, and there was no cultivation this year. None of the trees have ever been sprayed except those treated by Blodgett in 1913. As there was no fruit in the Ben Davis block last year, and consequently no record in Blodgett's bulletin, the fact that some of the trees were treated last year was overlooked in planning the experiment. Since the foliage of the entire block was well infected with scab in 1913, owing to the omission of the first and fourth applications, the conditions were fairly uniform except for a part of plat 3, plat 4 (used as a check), and plat 5, which did not receive treatment last year. In these plats the amount of foliage was greatly reduced in 1913 by various caterpillars, so that the actual amount of infection material under these trees was less than under the others. Plats 3 and 4 were so arranged as to avoid the necessity of drawing a load up and down the hill, and also to prevent waste by leakage. Under the circumstances it would have been better if each plat had extended full length up and down the hill.

Methods and materials used

The dusting machine was like that used in the other orchards. The spraying outfit was the same as was used last year (Fig. 30). The spraying was all done from the ground, with 10-foot spray poles (Fig. 29). As Blodgett had considerable difficulty with the engine in 1913, the New Way Motor Company kindly furnished an upright (instead of horizontal) 1½-horsepower engine, with which it was thought that some of the former difficulty might be overcome. There was much less trouble from the engine stalling than last year, but the desired number of revolutions per minute of the blower could not be maintained, particularly on rough ground. As the trees were low and small, the effectiveness of the work was not materially impaired; but in high trees or trees with a large spread, the outfit would have been inadequate. Aside from this defect the dust applications in this orchard were applied most satisfactorily. If the morning was calm, the dust was applied at once; but if there was wind, the dusting was left until late in the day when the wind had gone down. The latter condition prevailed in the case of two applications.

The use of wheat flour as a diluent in the dust mixture was tried in this orchard. The presence of the flour made the mixture flow much more freely, and there was consequent difficulty in gauging the outlet in order

X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
D	D	D	D	1	D	D	D	D	2	D	D	D	D	D	D	4	D	D	D	D	5	X
D	D	D	D	D	D	D	D	D	D	D	D	**D**^{2}	D	**D**^{3}	D	D	D	D	D	D	D	X
D	D	**D**^{3}	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	X
D	D	D	D	D	D	D	D	D	D	D	D	**D**^{1}	D	D	D	D	D	D	D	D	D	X
D	D	D	D	D	D	D	**D**^{3}	D	D	D	D	D	D	D	D	D	D	D	**D**^{3}	D	D	X
D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	3	D	D	D	D	D	X
D	D	**D**^{2}	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	X
D	D	D	D	D	D	D	**D**^{2}	D	D	D	D	D	D	D	D	D	D	D	**D**^{2}	D	D	X
D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	X
D	D	D	D	D	D	D	**D**^{1}	D	D	D	D	**D**^{2}	D	**D**^{3}	D	D	D	D	D	D	D	X
D	D	**D**^{1}	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	**D**^{1}	D	D	X
D	D	D	D	D	D	D	D	D	D	D	D	**D**^{1}	D	D	D	D	D	D	D	D	D	X
D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	X
S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S

N
W—|—E
S

FIG. 28.—*Chart showing plan of experiment performed in the Friedah orchard, Owego, New York. The Ben Davis trees (D) enclosed in the black lines represent the various plats, and the trees indicated by bold-faced type are the trees from which the apples were counted. The exponents refer to the order in which the data are presented in the table. D, Ben Davis; S, Northern Spy; X, mixed varieties. In plat 3, count trees 1 and 2, and those adjacent, were treated in 1913 with sulfur paste; count tree 3 is in the untreated plat of 1913. None of the trees in plats 4 and 5 were treated in 1913*

to apply the desired quantity of material per tree. In the cost figures of Table 9 the price of wheat flour is taken as 3 cents per pound.

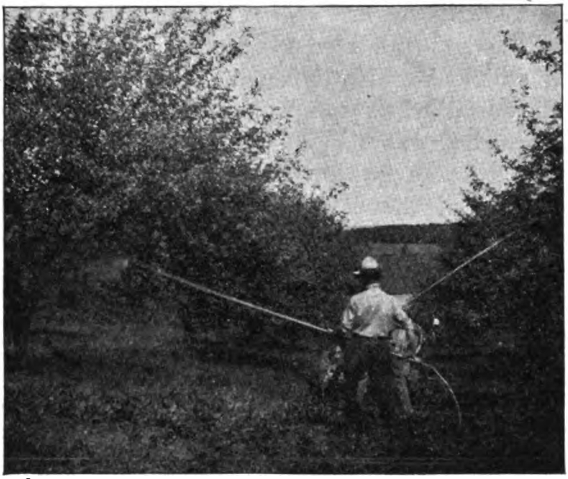


FIG. 29.—*Photograph made in the Friedah orchard. The size and shape of the trees is shown, also the method of applying the spray*

One plat (1) in this orchard was sprayed with a suspension of the finely ground sulfur of the dust mixture, to which was added 2 pounds of powdered arsenate of lead to each 100 gallons of water. The sulfur was easily brought into suspension by first wetting it with a weak glue solution.[7] A fine creamy paste resulted, which held up well and which passed very readily through the pump and the nozzles. Complete data on time and method of application are shown in Table 9. The cost of glue is not included in the cost of materials for the plat (1) treated with sulfur paste, and the time involved in driving to and from the orchard and in filling the tank is not included in the labor charges of the sprayed plats. This was never ess than thirty minutes for each 100 gallons of mixture.

No dormant treatment was made in this orchard, as San José scale was not known to exist there.

Three applications were made in the course of the summer, when the trees were in the same condition as in the other orchards. At the time of the first application, the spraying was done a day later than the dusting, but there was no intervention of rain or other unfavorable conditions. At the time of the second application, only the lower half of plat 3 was treated with lime-sulfur solution.[8] On the remainder of the plat sulfur paste was substituted. The treatment was the same for the third application.

[7] This mixture seems to have considerable value for certain spraying purposes. The exact method of preparation as used in this experiment is as follows: 2½ ounces of pulverized glue was dissolved in 2½ to 3 gallons of warm water; 20 pounds of the finely ground sulfur and 2 pounds of powdered arsenate of lead were weighed out into a large pail or other convenient receptacle. Glue solution was added as required, and was worked into the mixture by kneading with the hands. This required about five minutes. After the mixture was thoroughly wetted, it was thinned about one half with water and poured onto the strainer of the spray tank. The strainer consisted of a wooden box with a bottom of copper gauze, 20 meshes to the inch, supported by heavier galvanized gauze, 4 meshes to the inch. By turning the flow of water from the filling apparatus into the mixture, it was easily worked through the gauze with the hands or a brush.

[8] The shipment of lime-sulfur solution was lost in transit and none could be obtained in the vicinity; nor was quicklime available for boiling a small quantity.

As cankerworms and tent caterpillars threatened the destruction of the check plat, 2 pounds of powdered arsenate of lead was diluted with 50 pounds of wheat flour and dusted onto the trees of this plat on May 19. Although the quantity of poison applied was small, still it controlled these caterpillars fairly well, and on June 2 the foliage on these trees was in good condition and contrasted strikingly with the remaining untreated part of the orchard.

The relative quantities of essential ingredients applied per tree each time are on an average as follows: plat sprayed with lime-sulfur, sulfur 3.14 ounces, lead arsenate .99 ounce; plat dusted with 80-per-cent sulfur mixture, sulfur 21.89 ounces, lead arsenate 5.47 ounces; plat dusted with mixture containing wheat flour as a diluent, sulfur 13.44 ounces, lead arsenate 3.36 ounces; plat sprayed with paste sulfur, sulfur 8.32 ounces, lead arsenate .83 ounce.

Scab infection periods

In this orchard, as in the others, the scab disease was the only one of consequence. The early-infection period of May 11, 12, and 13 occurred in about the same severity as in the other orchards. At Waverly, in the Susquehanna Valley twenty miles west of Owego, there were periods that would permit a certain amount of infection on May 23, 26, and 27, May 29 and 30, June 4 and 5, June 7 and 8, June 15 and 16, June 19 to 22 inclusive, and June 27 to 29 inclusive. The infection periods during July were more numerous here than in the other orchards, but, as elsewhere, the majority of late-infection periods occurred in mid-August.

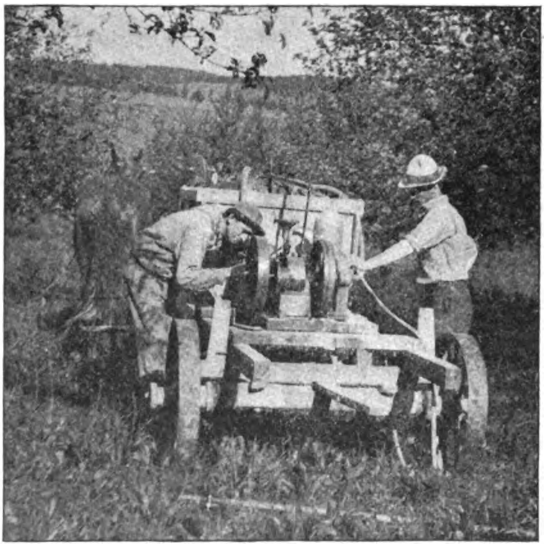


FIG. 30.—*Spraying outfit used in the Friedah orchard. Difficulty with the engine delayed the work and made many of the time records worthless*

Insects of the season

This orchard was badly infested by cankerworms, apple tent-caterpillars, and forest tent-caterpillars, and in the untreated part of the orchard many of the trees were nearly defoliated by these insects. Bud moths were no more abundant

TABLE 9. DATA ON TIME AND METHODS OF APPLICATION, FRIEDAH ORCHARD, OWEGO, NEW YORK

Date of application	Plat	Number of trees	Materials used, and strength	Quantity used	Time required						Cost			Cost per tree
					Horse		Man		Machine		Labor	Material	Total cost	
					Hrs.	Min.	Hrs.	Min.	Hrs.	Min.				
				(Gals.)										
May 20	3	56	Lime-sulfur solution (32°) 2.5 gallons, lead arsenate 2 pounds, water to make 100 gallons	150	*2	06	*3	09	*1	03	$ .84	$1.44	$2.28	$.041
June 2	3	56		200	2	06	3	09	1	03	.84	1.92	2.76	.049
June 20	3	56		170	2	06	3	09	1	03	.84	1.63	2.47	.044
Totals	....	....	....	520	6	18	9	27	3	09	$2.52	$4.99	$7.51	$.134
				(Lbs.)										
May 19	2	65	Sulfur 80, lead arsenate 20	65	0	40	0	40	0	20	$.20	$ 3.43	$ 3.63	$.056
June 2	2	65		140	1	10	1	10	0	35	.35	7.39	7.74	.119
June 20	2	65		130	1	20	1	20	0	40	.40	6.86	7.26	.112
Totals	....	....	....	335	3	10	3	10	1	35	$.95	$17.68	$18.63	$.287
May 19	5	65	Sulfur 40, lead arsenate 10, wheat flour 50	90	0	36	0	36	0	18	$.18	$ 3.73	$ 3.91	$.060
June 2	5	65		170	1	16	1	16	0	38	.38	7.04	7.42	.114
June 20	5	65		150	1	12	1	12	0	36	.36	6.21	6.57	.101
Totals	....	....	....	410	3	04	3	04	1	32	$.92	$16.98	$17.90	$.275
				(Gals.)										
May 20	1	65	Sulfur 20 pounds, lead arsenate 2 pounds, water to make 100 gallons	160	2	06	3	09	1	03	$ .84	$1.25	$2.09	$.032
June 2	1	65		200	2	06	3	09	1	03	.84	1.56	2.40	.037
June 20	1	65		150	2	06	3	09	1	03	.84	1.17	2.01	.031
Totals	....	....	....	510	6	18	9	27	3	09	$2.52	$3.98	$6.50	$.100

* The figures given here are the average of time required per tree multiplied by the number of trees of all the satisfactory runs made throughout the season. A number of runs were greatly disrupted by various sorts of troubles. The average given here is much more nearly correct than would be the actual time involved.

than in the Catchpole orchard, but cigar case-bearers were very plentiful. Leaf rollers were abundant, but some of the injury attributed to these insects at the time of counting may have been caused by tent caterpillars and possibly by the white-marked tussock-moth caterpillar. For some unknown reason, the codling moth was not so abundant as would be expected in an orchard so badly neglected.

Results of experiments

Scab control.— The first applications, on May 19 and 20, were made opportunely to afford protection against infections occurring late in May. As the primary infections of May 11 had not developed conidia until near June 1, infections occurring in May were from ascospores. The number of infections was obviously much less than if conidia had been present, and the amount of pedicel infection was so slight as to be a negligible factor. Judging from the other orchards, it is probable that conidia were liberated from scab spots on May 29 and 30, when the conditions apparently were very favorable for infection. The blossoms had all fallen on this date, and the Waverly record shows dense fog on May 29 with slight precipitation on May 30. Subsequent observations indicate strongly that a large amount of secondary infection occurred at this time. The second application, on June 2, afforded protection against the infections of June 4 and 5, which was decidedly the most favorable period for infection prior to the rains beginning on June 19.

The third application, on June 20, following the heavy rain during the afternoon and night of June 19, unquestionably was made too late to prevent the greatest infection of the season, although additional infections occurring on June 21 and 22 were forestalled.

By July 1, when the orchard was examined, it was evident that there was a large amount of scab infection on all the treated plats. Drops in this orchard were destroyed by hogs, except those that were caught in cheesecloth hammocks. The pedicels were practically free from infection, and, as there was no indication on July 1 that the scab disease was in any way responsible for the dropping of fruit, no record was made of the percentage of scab on the small number of drops caught. No thinning was done in this orchard. The late application was omitted intentionally.

It is obvious from Table 10 that very poor control of scab resulted on any of the plats. The order of effectiveness of early-scab control for the various materials may be an indication of the relative value of the substances tested, but this order coincides with the order of application of the materials at the time of the third application. Plat 3 (lime-sulfur solution) was treated in the morning, plat 1 (sulfur paste)

TABLE 10. CLASSIFICATION OF PICKED BEN DAVIS APPLES FROM THE FRIEDAH ORCHARD, OWEGO, NEW YORK

Treatment	Total number of apples	Sound		Unsound		Apple scab				Leaf roller and green fruit-worm		Bud moth		Codling moth	
						Early		Late							
		Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Untreated	629	1	0.16	628	99.84	620	98.57	608	96.66	145	23.05	3	0.4769	14	2.2258
	556	1	0.18	555	99.82	550	98.92	530	95.32	148	26.62	2	0.3597	16	2.8777
	1,000	0	0	1,000	100.00	952	95.20	973	97.30	297	29.70	3	0.3000	16	1.6000
Total	2,185	2		2,183		2,122		2,111		590		8		46	
Mean			0.11		99.89		97.56		96.43		26.46		0.3789		2.2345
Probable error			±.038		±.038		±.76		±.04		±1.36		±.035		±.247
Average			.09		99.91		97.12		96.61		27.00		0.3661		2.1053
Lime-sulfur solution (32°) 2.5 gallons, lead arsenate 2 pounds, water to make 100 gallons	4,126	2,236	54.19	1,890	45.81	1,262	30.59	1,384	33.54	268	6.50	12	0.2908	2	0.0485
	2,418	1,393	57.61	1,025	42.39	565	23.37	619	25.60	350	14.47	5	0.2068	0	
	2,049	873	42.61	1,176	57.39	837	40.85	891	43.48	237	11.57	3	0.1464	2	0.0976
Total	8,593	4,502		4,091		2,664		2,894		855		20		4	
Mean			51.47		48.53		31.60		34.21		10.85		0.2147		0.0487
Probable error			±3.04		±3.04		±2.42		±3.46		±1.56		±.345		±.0189
Average			52.39		47.61		31.00		33.68		9.95		0.2321		0.0466
Sulfur 80, lead arsenate 20	3,485	1,013	29.07	2,472	70.93	1,508	43.27	2,293	65.80	112	3.21	12	0.3443	2	0.0574
	2,666	846	31.73	1,820	68.27	1,074	40.29	1,622	60.84	66	2.48	7	0.2626	0	
	2,641	501	18.97	2,140	81.03	1,748	66.19	1,994	75.50	249	9.43	6	0.2272	7	0.2651
Total	8,792	2,360		6,432		4,330		5,909		427		25		9	
Mean			26.59		73.41		49.92		67.38		5.04		0.2780		0.1075
Probable error			±2.61		±2.61		±5.48		±2.89		±1.47		±.048		±.054
Average			26.84		73.16		49.25		67.21		4.86		0.2843		0.1024
Sulfur 20, lead arsenate 2, water to make 100 gallons	4,014	1,753	43.67	2,261	56.33	1,337	33.31	2,060	51.32	67	1.67	18	0.4484	9	0.2242
	2,978	978	32.84	2,000	67.16	1,130	37.94	1,368	45.94	100	3.36	0		0	
	3,034	886	29.20	2,148	70.80	1,410	46.47	1,669	55.01	546	18.00	5	0.1648	6	0.1978
Total	10,026	3,617		6,409		3,877		5,097		713		23		15	
Mean			35.24		64.76		39.24		50.76		7.68		0.2044		0.1407
Probable error			±2.91		±2.91		±2.59		±1.76		±3.47		±.088		±.047
Average			36.08		63.92		38.67		50.84		7.11		0.2294		0.1496
Sulfur 40, lead arsenate 10, wheat flour 50	*1,000	231	23.10	769	76.90	564	56.40	693	69.30	96	9.60			0	
	*1,000	337	33.70	663	66.30	460	46.00	443	44.30	200	20.00			0	
	*1,000	275	27.50	725	72.50	573	57.30	563	56.30	109	10.90			0	
Total	3,000	843		2,157		1,597		1,699		405					
Mean			28.10		71.90		53.23		56.63		13.50				
Average			28.10		71.90		53.23		56.63		13.50				

*Not all the apples from the trees were counted.

was begun at one o'clock in the afternoon and finished about four o'clock, and the two dusted plats were treated after five o'clock in the afternoon. In view of the observations and records of Wallace[9] (page 570 and Plate XI of reference cited), it seems quite possible that the application of lime-sulfur made approximately eighteen hours after the rains set in prevented a certain amount of infection which applications six hours later, or even one hour later, would not have prevented. One of the strongest reasons for believing that this factor enters is that in Blodgett's experiments[10] sulfur dust and sulfur paste were equally effective in scab control, whereas in this orchard the difference is pronounced (being 10 per cent), and the difference between the percentage of scab control with lime-sulfur solution and either dust or paste is much greater than it was last year.

The control of late scab, as in the Glidden orchard, varies directly with the control of early scab, and, as in the other orchards, apples bearing early-scab spots were almost certain to show late infection also.

Insect control.— In this orchard all the treatments greatly decreased the injury caused by leaf roller, the best results being obtained by the use of the sulfur and lead-arsenate in dust form. Only 2.1 per cent of the apples in the check plat were injured by the codling moth; all the treatments given reduced this injury to less than 1 per cent.

GENERAL SUMMARY

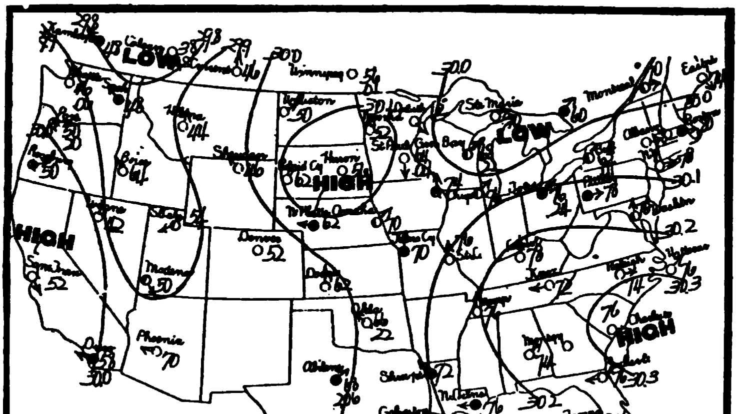
Material progress has been made in answering the six points to be determined as outlined at the beginning of this bulletin, and a number of additional observations bearing on the general project may be recorded:

1. The dust method seems to be particularly applicable to large old trees, with which the difficulty in doing thorough spraying is most apparent.

2. It is well understood that, in dealing with nature, things rarely happen twice alike. With the information now at hand, a schedule could be made which, if followed, would give a complete and satisfying answer to the second point. Whether or not the results of last year have been duplicated or improved may appear to depend on which orchard is chosen or on an average of the three orchards. It does not. It depends on an interpretation of the data secured in the light of known biological and physical phenomena, and in this instance more particularly in the light of the facts known about the apple scab fungus.

That the scab fungus would mature earlier than usual in 1914 might have been determined in advance, but the practicability of making an application of spray to prevent the early infection is doubtful. It probably would have been a physical impossibility in two of the orchards,

[9] Wallace, Errett. Scab disease of apples. Cornell Univ. Agr. Exp. Sta. Bul. 335 : 545–624. 1913.
[10] See Table 5 in Bulletin 340 of the Cornell University Agricultural Experiment Station.



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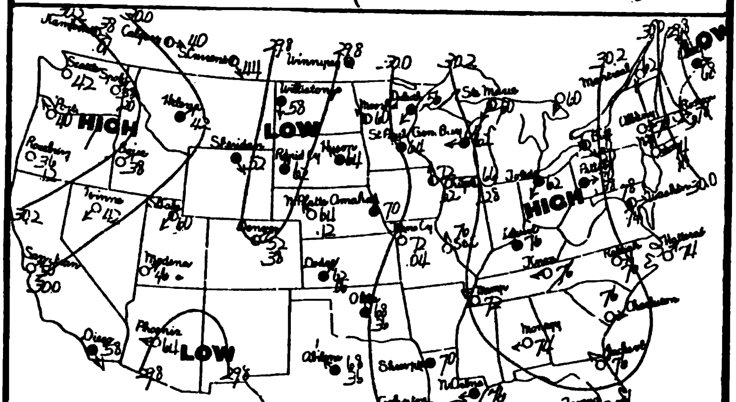

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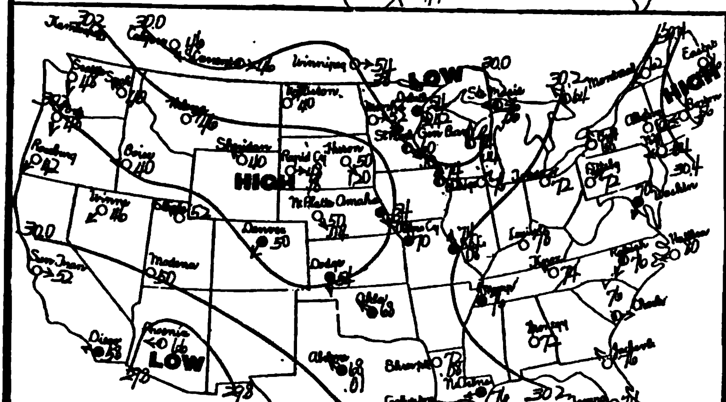

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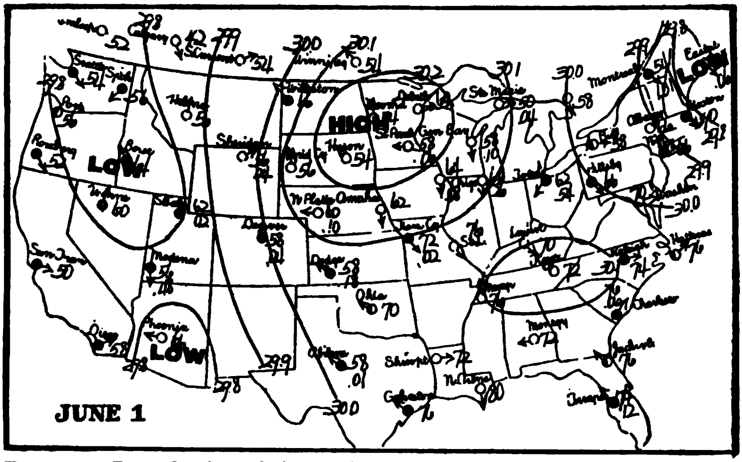
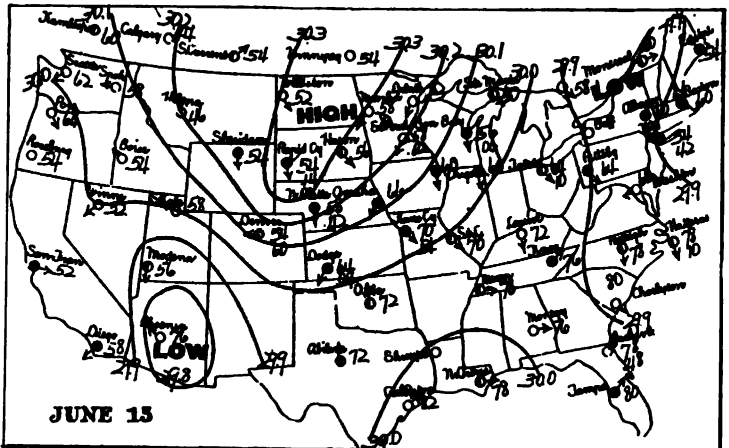


FIG. 31.—*Reproduction of the weather maps issued on May 27, 28, 29, and June 1. Conditions on May 27 were favorable for rain within a few hours. The "Low" central over Lake Huron on this date had been moving eastward for two days, and caused the writers great anxiety. The fact that the center was above the lakes afforded some relief, but the map of May 28 revealed a new menace. This area fortunately lost in intensity, but permitted some rainfall on May 30 (May 30 being a holiday, no map was made on that day)*

because of the soft condition of the soil. A dusting outfit could have been used. Such an application would have afforded no pedicel protection, but this year such protection was not needed.

The second application should have been made earlier. The trees were in a suitable stage for treatment several days earlier than the actual date of application. While this fact was fully realized at the time, and weather charts (Fig. 31) indicated the occurrence of rain, one of the writers (C) was at that time unfamiliar with the details of the experiments and the other was detained in Ithaca with five days of work which could not be delegated. That the infection at Holley was slight on May 28 is purely accidental, since general conditions existed which might have permitted a considerable infection.

The third application was being timed with special reference to codling moth, but of course due regard was taken of possible scab-infection periods. It was decided tentatively by one of the writers (C) to begin the work of making the application on June 18. Weather conditions on the previous days, as can be seen from the accompanying reproductions of the maps for those days (Fig. 32), did not indicate that a serious disturbance was imminent, and indeed the forecast of the observers on June 18 was for fair weather. It will be noticed from the maps that an area of insignificant extent was responsible for the downpour of June 19. Again,



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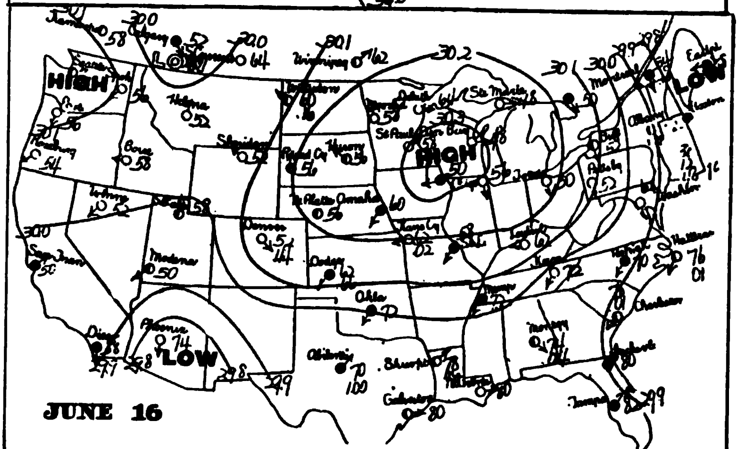

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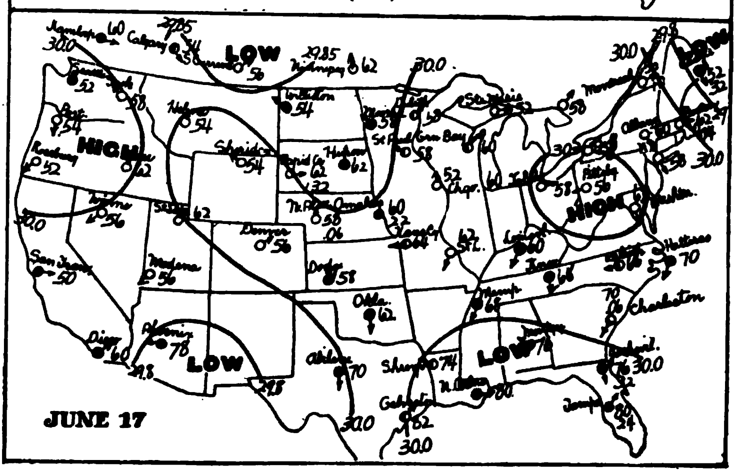

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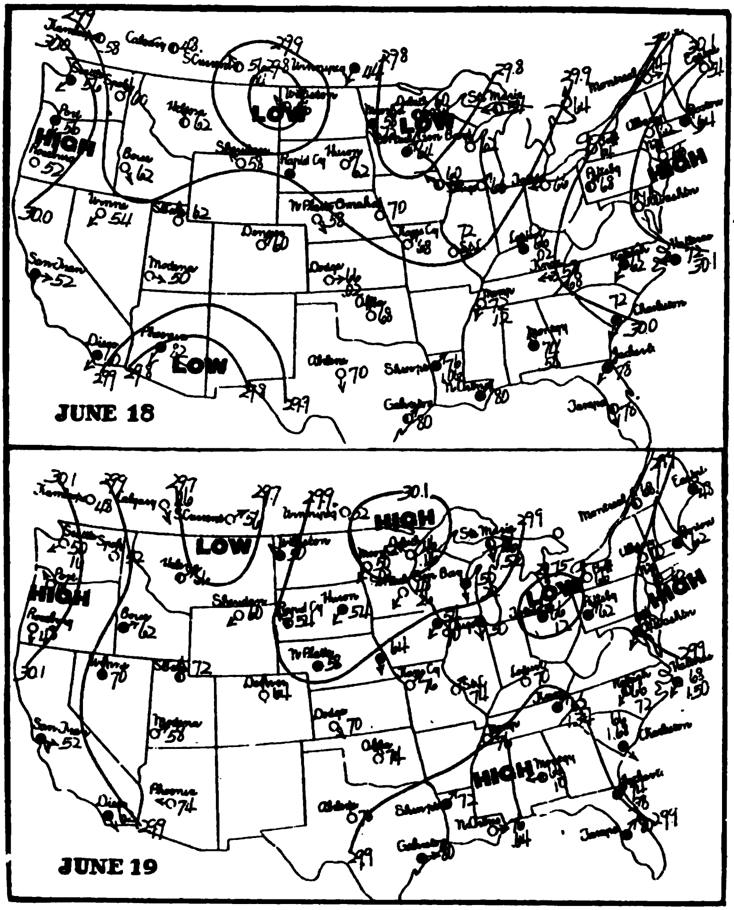


FIG. 32.—*Reproduction of the weather maps issued on June 15, 16, 17, 18, and 19, 1914. The disturbance (indicated by the word "Low") in the Canadian Northwest on June 17 might have been expected to reach New York in three or four days, thus allowing ample time to protect all the experimental orchards. Instead, on June 18 there are two storm centers, and at eight o'clock in the morning on Jxne 19 one of them is central over Lake Erie. The area was insignificant in extent, but it was large enough to involve all three orchards*

it was, in a way, only accidental that the Glidden orchard was treated in time to forestall the heavy infection of June 19. The low barometer showing for the first time on June 17 in the Canadian Northwest was the one that might bring rain. That it would split, and a small part move across the country at great velocity, bringing in its wake a torrent of rain that would involve the three rather widely separated experimental orchards, was certainly not anticipated by the writers, who do not profess

to be weather prophets. As a result of the disturbance, the general unsettled condition indicated in the map of June 20 reached western New York on June 21 and continued for four days.

The test in the Glidden orchard was a fairly severe one, inasmuch as the unsprayed trees, which previously had been well sprayed annually for at least seven years, developed 35 per cent of scabby apples.

In the writers' opinion, therefore, the results obtained in the Glidden orchard should receive the most consideration, and on that basis the question may be answered by saying that the results of 1913 have been approximated so far as scab is concerned.

Aside from insect and disease control, the mechanical difficulties of former years were decidedly reduced, and from this standpoint the work of the season has been a great improvement over that of former years.

The removal of mechanical difficulties has made it possible to secure more reliable cost data than could be obtained formerly, and it now appears that an orchard may be protected by dusting at the same cost per tree as by spraying, or at less cost.

3. The tests of the various mixtures on insect control were not so severe as in former years, and the absence of codling moth in all three orchards leaves the control of this important pest out of consideration. It appears, however, that the dust mixtures containing 10 per cent of arsenate of lead are as effective as those containing twice the quantity.

4. It would appear that the quantity of sulfur applied per tree may be reduced. By comparing the percentage of early apple scab in plats 3 and 5 of the Glidden orchard, or in the two dusted plats in the Friedah orchard, it will be seen that they are very close together. This can only indicate that some trees received 50 per cent more sulfur than was necessary. The fact that the gypsum plat in the Catchpole orchard runs higher in scab is thought to be an indication of less thorough application (because of wind) rather than of reduced fungicidal value.

5. To the fifth question a satisfactory answer has not been secured. The results with hydrated lime are indecisive, as they are quite different in the two orchards where this substance was used. In the Glidden orchard the heavy shower following immediately after the first application of the mixture containing lime may have washed off the material before it was set, while in the Catchpole orchard the more favorable showing of the lime-dusted plat may be attributed to one of two things — the application of bordeaux mixture on May 14, or more satisfactory applications of dust due to the fact that adjacent woods broke the force of the wind in this area. The latter is the more probable explanation.

The use of gypsum did not seem to add to or detract from the adhesiveness of the mixture.

Wheat flour did not add materially to the adhesive properties of the mixture, and the expense of this substance practically precludes its use.

6. The paste sulfur, although applied very cheaply, does not seem to be the equal of lime-sulfur solution. However, the test cannot be regarded as conclusive.

OTHER GENERALIZATIONS

In addition to the above considerations, observations have been made on a number of points about which there has been considerable inquiry.

Destruction of fallen leaves

That fallen leaves are the source of primary scab infection in these orchards is unquestionable. It is also very evident from this work that the amount of secondary infection is directly dependent on the abundance of primary infection. Everything points to the conclusion that the early destruction of the fallen leaves (sometime previous to May 11) would have materially reduced the number of primary infections and would have made the control of secondary infections easier. At least two of the orchards might have been plowed at any time during the month of December, 1913. It is doubtful whether any of them could have been plowed in April or early May of 1914, because of the wet condition of the soil. Plowing under the old leaves, however, will never be so effective as to make the application of fungicides unnecessary.

What makes dust stick?

There have been many inquiries as to what it is that makes the dust preparations adhere to the foliage. There seem to be at least two factors involved, possibly more. During the early period of growth of the leaf and the fruit, a dense mat of fine plant hairs covers each. The particles of the dust mixture are fine enough to lodge between these hairs, and are there protected from wind and rain. It appears, therefore, that the fineness of the material is an important item.[11] The same hairs are effective in holding many spores of the scab fungus in place until they have had time to germinate.

The other factor of importance is the adhesive nature of some of the lead compounds. The white lead of commerce is well known because of this property. When lead arsenate is moistened, it becomes somewhat gelatinous and is difficult to wash off completely. This was brought forcibly to the attention of one of the writers (R) when, after completing a job of dusting, he undertook to wash the dust from his hair with soap and water.

[11] The sulfur used in all these experiments is much finer than the ordinary sulfur flour or even flowers of sulfur. At least 95 per cent will pass a 200-mesh screen. Comparative sizes of individual particles of the various kinds of sulfur are illustrated by photomicrographs, and the method of testing the fineness is described by Blodgett (Cornell Univ. Agr. Exp. Sta. Bul. 328 : 306-310, figs. 108-110. 1913).

Each hair seemed to become covered with a film of the mixture. Finally a barber was resorted to for relief. This homely experience has increased the writers' respect for the adhesiveness of a mixture containing arsenate of lead, and leads them to believe that this may help to explain how the mixture sticks to the trees. The moisture, of course, is supplied by the dew of the succeeding night or by gentle rains.

Must dust be applied at special times?

There is an idea prevalent that dust must be applied very early in the morning in order that advantage may be taken of the dew on the trees. Doubtless this would be an advantage in causing the mixture to set at once, but in the minds of most New York orchardists it is impracticable. In localities where wind is a factor, early morning applications before the wind comes up would be desirable. It usually happens, however, that there are a few days of calm weather between the storm periods, during which dusting or spraying can be done advantageously.

Aside from the points mentioned above, the time of application of dust does not differ from that of applying spray with possibly one exception. If before a given application is finished a heavy rain should come early in the morning (as early as three o'clock) and be followed by a day of fog, it would be profitable to run the duster at full capacity for most of the day. Spraying, of course, could not be done because of wet ground and the drip from the foliage.

Is there danger from breathing the dust?

In regular work there is little necessity for breathing the dust, except for the slight leakage about the machine, in turning at the ends of rows when there is some wind, and in filling the hopper. In case of frequent changes of materials and in the short rows of experimental work, a number of different persons (the writers included) have breathed considerable quantities of the dust. No inconvenience has been experienced by any one, and no unfavorable symptoms of anything like lead poisoning.

Special equipment needed

Aside from the mounted dusting machine and engine, no special equipment is needed except a pair of goggles for the operator and one for the driver. A very small quantity of sulfur dust in the eyes causes an irritation which becomes noticeable only after an hour or more and which is aggravated by rubbing. A pair of goggles that fit tightly about the eyes and cover the least possible extent of surface is desirable. The larger kinds are likely to become fogged from perspiration.

Sow oats, or dust?

Every fruit grower knows that there are times when the teams on the spraying outfit are sorely needed for plowing, for fitting the land, or for seeding. By employing the dust method, the labor item in protecting the orchard may be reduced nearly one fourth. Whether the duster or sprayer should be run on any certain day in preference to doing other farm work, is the one point about which effective disease control hinges. First of all, the trees must be in condition for an effective application. Aside from that, the determining point should be based on a prognostication of the next storm period. If the dependence of scab infection on rainfall and attendant weather conditions was ever in doubt, the work presented in this bulletin would dispel such doubt. Any one can learn to make intelligent use of the forecasts of the United States Weather Bureau, and by going back of the twenty-four-hour forecast and examining the maps from which the forecast was made one can determine in a general way what may happen in the next two or three days. If there are probabilities of a general storm period within forty-eight hours, the orchard should be protected regardless of other farm operations. If no maps can be consulted, but the wind is in the east and has been in the east or the northeast on the day before, there is sufficient reason in most parts of the State for running the duster in preference to the grain drill. The oats will grow if put in after the rain, but orchard treatments after the rain will not prevent scab infection.

Who shall dust?

There is no indication that the spray machine can be thrown on the scrap heap. In fact, with our present knowledge, it is quite certain that the trees must be sprayed in the dormant stage just as in the past. The man who can cover his entire orchard in three to four days will doubtless continue spraying as in the past. Where the relation of orchard to farm is such as to throw an unusual load of labor on men and teams during May and June, and where the orchard is of such extent that it is practically impossible to equip enough outfits to do the spraying at critical times, the duster will afford necessary relief. For the present, at least, it seems desirable, in case both duster and sprayer are used, to apply the liquid to varieties most susceptible to scab.

On a good day — and there are usually two or more comparatively calm days between storm periods at this time of year — one can expect to cover six hundred to nine hundred trees in ten hours. If the trees are small and the horses walk briskly, more trees can be covered. This experimental work has been done almost entirely from the point of view of the commercial orchardist. Its applications, however, extend to practically all owners of apple trees, and particularly to the general farmer with a few trees in the

home orchard. It is very exceptional to find small orchards that are sprayed. On the general farm the dates of application are too inopportune, and it usually happens that the only spraying outfit available is traction-driven. Such outfits usually do not give satisfaction in the orchard. With the dust method one man, the hack horse hitched to the democrat wagon, and a small hand machine that is always in readiness for operation, are the only equipment necessary.

What materials shall be used?

The tests of recent years have been made with a very fine sulfur flour combined with dry arsenate of lead, and any combination other than this should be used only in an experimental way. Whether an inert carrier, such as powdered gypsum, should be added, or whether a smaller quantity of the undiluted mixture should be applied per tree, is an open question. For the present it would be advisable to use a mixture of 90 parts of pure sulfur specially finely ground and 10 parts of powdered arsenate of lead, applying, on an average, 1½ to 3 pounds of the mixture per tree at each application. If the grower desires to compound his materials he should procure a suitable mixing outfit. Experience in diluting lead arsenate for the treatment of the check plat in the Friedah orchard makes it certain that, with the average equipment about the farm, a grower cannot make a suitable mixture economically.

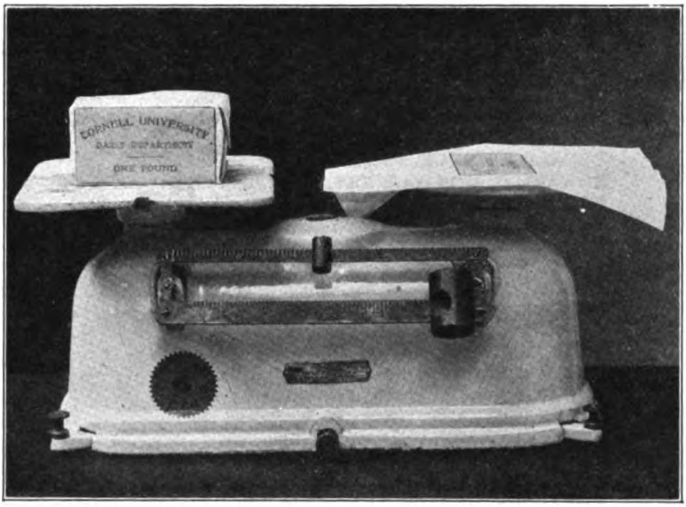
CORNELL UNIVERSITY

AGRICULTURAL EXPERIMENT STATION OF

THE COLLEGE OF AGRICULTURE

Department of Dairy Industry

TWO FACTORS CAUSING VARIATION IN THE WEIGHT OF PRINT BUTTER



By H. M. PICKERILL AND E. S. GUTHRIE

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TWO FACTORS CAUSING VARIATION IN THE WEIGHT OF PRINT BUTTER

H. M. Pickerill and E. S. Guthrie

A law passed by the New York State Legislature in 1912 requires that print butter shall be stamped with its correct weight. This law reads as follows[1]:

"The maximum variation allowed on a pound print to be three-eighths of an ounce on an individual print, provided that the average error of twelve prints, taken at random, shall not be over one-fourth of an ounce per pound. The maximum variation allowed on two-pound prints to be one-half ounce, provided that the shortage on twelve prints, taken at random, be not more than three-eighths of an ounce for two pounds.

"Prints that are not of one pound or two pounds must be marked in letters at least three-eighths of an inch in height, giving the correct weight in terms of ounces or pounds and ounces."

It is purposed to point out, in this bulletin, the variation that may occur in the weight of butter because of a difference in pore space and because of shrinkage taking place after the butter is made up in one-pound bricks and wrapped in parchment paper.

VARIATION DUE TO PORE SPACE

There is considerable variation in the amount of pore space in butter taken from different churnings. This is important, because prints are cut by volume and because individual prints are seldom weighed. It is evident that the greater the amount of pore space, the less a given volume will weigh.

Rogers,[2] when he worked on the fishy flavor found in butter, studied the amount of air that might be incorporated. His method consisted in determining the amount of oxygen that was incorporated, and then computing the increased air content. He says: "Butter badly overworked with a spatula always shows a distinctly higher oxygen content than an unworked portion of the same sample when they are compared by this method. The difference is usually equivalent to about 0.2 cubic centimeter of gas absorbable by alkaline pyrogallic acid solution for every 10 grams of butter when measured under these conditions. This indicates an increased air content of over 10 per cent. With butter overworked in a churn the difference is small but distinct."

According to Rogers' work, the increase in air content of butter is much smaller than some of the differences noted in this work. If the original pore space of a piece of butter were 3 per cent and it increased 10 per cent, as Rogers finds, it would then be only 3.3 per cent.

The method used in these studies for determining the pore space of butter was to find the weight of the butter, its volume, and the average

[1] From New York State Weights and Measures Bulletin, New Series. No. 3. December, 1914.
[2] Rogers, L. A. Fishy flavor in butter. U. S. Animal Indus. Bur. Circ. 146:15–16. 1909.

specific gravity of the butter constituents taken collectively. In detail the method used in calculating the amount of pore space requires the use of a wide-mouth bottle, the exact capacity of which is known when it is filled to a point indicated by a file mark on the outside. The weight and volume of a piece of butter are then determined as follows:

A. Weight of flask = 323.4 grams
B. Weight of flask + butter = 397.7 grams
C. Weight of flask + butter + water to file mark = 898.3 grams
B — A = weight of butter, 74.3 grams
C — B = weight of water, 500.6 grams
C — B = also the volume of water at 0° C., 500.6 cubic centimeters
Volume of water at 10° C. = 500.85 cubic centimeters
Capacity of bottle to file mark = 578.00 cubic centimeters
578.00 (capacity of bottle) — 500.85 (volume of water) = volume of butter, 77.15 cubic centimeters

In order to find the average specific gravity of the butter constituents, which is the absolute specific gravity of the butter, the percentage of each constituent is multiplied by the specific gravity of that constituent, and the sum of the products is divided by 100. The result is obtained as follows:

Moisture	13.9 x 1[3] =	13.900
Salt	2.8 x 2.164[4] =	6.048
Curd[5]	.5 x 1.4[3] =	.700
Fat	82.8 x .94[3] =	77.832
Total...	100.0	98.480

98.48 ÷ 100 = .9848. This is the average specific gravity of the butter constituents, or the absolute specific gravity of the butter.

In order to calculate the pore space from the volume, weight, and absolute specific gravity, the volume, 77.15, is multiplied by the absolute specific gravity, .9848. This gives 75.977, the number of grams the piece of butter would weigh if there were no pore space. This is the volume weight. The butter, however, weighs only 74.3 grams, which shows that there is a certain amount of pore space present. When calculated exactly, the percentage of pore space is found to be as follows:

$$\frac{75.977 - 74.3}{75.977} \times 100 = 2.2, \text{ percentage of pore space}$$

In order to determine to what extent the pore space in different churnings varies from day to day, tests of the butter at the college creamery have been made on a number of days. The following data were collected:

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[3] From *Dairy Chemistry*, edition of 1899, page 65. By Henry Droop Richmond. The increase above specific gravities because of low temperatures was estimated by Richmond.
[4] From *Treatise on Chemistry*, volume 2, page 252. By Roscoe and Schorlemmer.
[5] In the first samples the percentage of curd was determined by the Kjeldahl method; but it was found to vary so slightly from .5 of 1 per cent that in subsequent experiments the exact percentage was not determined.

Date	Percentage of pore space	Date	Percentage of pore space
May 14, 1912	2.00	June 4	4.20
15	4.00	5	6.00
16	4.00	7	0.50
17	5.00	10	3.60
18	5.00	12	2.60
21	3.60	21	3.80
22	3.40	24	4.00
28	3.00	25	3.30
29	5.70	26	2.90
29	5.40	July 5	2.30
June 3	2.90	9	4.00

In these tests the amount varies from .5 of 1 per cent to 6 per cent, the average being 3.69 per cent.

Let it be supposed that the printing machine was set to cut exactly one-pound prints when the pore space was 2 per cent. If on the next day the pore space was 6 per cent, the prints would actually weigh 15.4 ounces, or only 96 per cent as much as on the day preceding. It is important, therefore, that the manufacturer weigh the first few prints made from each churning, in order to determine whether they are being cut too heavy or too light.

In computing the amount of pore space, it was thought wise to determine the experimental error so far as possible. Data were obtained in the following manner: Two one-pound prints were taken from the same churning, and from these two prints six determinations of the pore space were made. The following results are recorded:

Print	Percentage of pore space	Print	Percentage of pore space
1	3.1	2	2.2
1	2.2	2	3.0
1	1.7	2	1.8

Six prints were taken from the same part of another churning, and half of each print was studied. The following percentages of pore space were shown in these prints:

Print	Percentage of pore space	Print	Percentage of pore space
1	4.75	4	5.78
1	5.33	4	5.99
2	4.74	5	5.56
2	......	5	4.58
3	4.60	6	5.17
3	3.90	6	6.16

Some of the above variations may be due to error in making the determinations. But it is readily seen that the butter is not constant, even when

it is taken from the same spot in the churn, because there may be air pockets due to improper packing in the printing machine or for other reasons.

If in old butter some of the moisture evaporates, it seems evident that the amount of pore space would be the space originally present plus the space left by the evaporated moisture. Some tests were made on butter several months old, with the following results:

Sample	Percentage of pore space
1	11.4
2	4.0
3	6.8
4	9.7
5	14.9
6	7.3

The amount of pore space in these samples when first made is not known, but the results found when the butter was old show a higher percentage than any others thus far recorded. This condition seems to warrant the assumption that age causes an increase in the amount of pore space. The explanation of this is probably to be found in the evaporation of moisture from the samples. In general, their moisture content was low, being only 9 per cent in some instances.

VARIATION DUE TO SHRINKAGE OF PRINTS

The second factor studied is the shrinkage that takes place after the butter has been printed and before it reaches the consumer.

Willard[6] reports a loss by shrinkage of a little less than half an ounce per print on five one-pound bricks of butter that were kept from December 29, 1909, to July 6, 1910, in an average creamery refrigerator; these prints were wrapped in parchment paper and placed in paraffined cartons. At the same time fifty one-pound prints that were wrapped in parchment paper and placed in paraffined cartons were put into a wooden case and placed in cold storage; they were removed from the refrigerator on March 2, 1910, with no shrinkage. Five prints that were wrapped in parchment paper and put into paraffined cartons were placed in a living-room five feet from a radiator; on April 22, 1910, the loss was a little less than an ounce per brick. Five one-pound prints were wrapped in double parchment paper and put into paraffined cartons; on April 22, 1910, after a period of more than three months in an open cabinet in a hall, the evaporation was a little over one-half ounce per print. Nine prints were wrapped in double parchment paper and put into paraffined cartons with an outside wrapper; after a period of almost five months in a creamery refrigerator, the loss by shrinkage was about one-fifth of an ounce. Thirty one-pound prints that were wrapped in the same manner as the above

[6] Willard, J. T. Changes in weight of stored flour and butter. Kansas State Board of Health. Bul. no. 1, vol. 7, p. 9. 1911.

nine prints were put into a fiber-board carrying case and placed in cold storage; the weight of the prints remained constant throughout the test, which lasted four months.

Frevert[7] says: "Under store conditions, one-pound prints of butter shrink about one-fourth ounce in the first seven days. Ranch butter shrinks more than creamery butter and two-pound prints shrink less in proportion to their weight than one-pound prints."

The conditions that were studied, and the ones that are probably most important, are in the following list:

1. Effect of the temperature of the place of storage.
2. Effect of the humidity of the atmosphere.
3. Effect of the length of time in storage.
4. Effect of the weight of paper used for wrapping.
5. Effect of packing in cartons, dry in wrappers, or wet.
6. Effect of storage in refrigerators or in show cases, when the individual prints are set on shelves.

In all cases the prints were weighed on scales adjusted to read to thirty-seconds of an ounce, and only the weights of individual prints were recorded. The figures representing weights given in the tables of this bulletin are expressed in thirty-seconds of an ounce above or below one pound; figures representing weights below one pound are preceded by a minus sign. The same ten prints were taken from the box and weighed daily; each print weighed was given a number, and its position in the box is indicated in Figure 33.

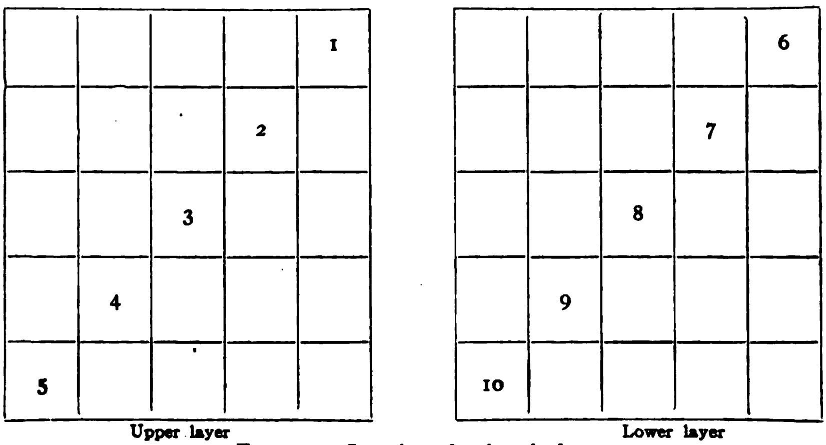

Fig. 33.—*Location of prints in box*

Effect of temperature and humidity of the place of storage

The barometric pressure was not made a part of this study, since it is of slight importance. The temperature and the humidity of the

[7] Frevert, G. E. A study of Idaho butter, with suggestions for improvement. Idaho Agr. Exp. Sta. Bul. 73:47, 52. 1912.

refrigerator were recorded by the wet-and-dry-bulb method. In Tables 1, 2, and 3, the figures for these two conditions are averages of the records for twenty-four hours:

TABLE 1.— EFFECT OF A COMPARATIVELY HIGH TEMPERATURE AND A COMPARATIVELY LOW HUMIDITY ON LOSS IN WEIGHT OF PRINT BUTTER

Temperature of storage room (degrees Fahrenheit)		67	67	67	67	68	69	68	68	69	69	Average temperature 68	
Humidity of storage room		77	80	80	79	74	79	80	79	80	80	Average humidity 79	
Number of days in storage room		1	2	3	4	5	6	7	8	9	10		
												Total loss	
Position	Number of prints	Weight*										In thirty-seconds of an ounce	In decimals of an ounce
1	13	7.0	5.0	3.0	3.0	2.6	0.5	—0.7	—2.0	—2.5	—3.0	10.0	.31
2	13	6.0	5.3	3.0	2.6	2.4	1.0	0.0	—1.6	—1.6	—2.0	8.0	.25
3	13	6.0	4.0	2.0	2.0	1.7	—0.5	—1.0	—2.4	—3.0	—3.0	9.0	.28
4	13	3.5	1.4	1.0	0.0	—2.6	—3.0	—4.0	—5.0	—5.0	—5.3	8.8	.28
5	13	7.0	5.9	2.0	2.5	1.0	0.0	—1.0	—2.0	—2.0	—2.3	9.3	.29
6	13	6.0	5.4	3.7	2.4	1.0	0.0	—0.5	—1.7	—3.0	—3.0	9.0	.28
7	13	1.0	0.0	0.0	—1.0	—2.7	—3.0	—4.0	—4.5	—6.0	—6.0	7.0	.22
8	13	—1.0	—1.0	—1.6	—2.0	—3.7	—4.0	—5.0	—6.0	—6.0	—6.0	5.0	.16
9	13	—1.0	—1.4	—2.0	—3.0	—4.0	—4.0	—4.0	—5.5	—6.0	—7.0	6.0	.19
10	13	4.0	3.2	2.2	1.3	0.0	—1.0	—1.0	—2.6	—3.0	—3.5	7.5	.23
Average for 130 prints		3.9	2.8	1.3	0.8	—0.4	—1.4	—2.1	—3.3	—3.8	—4.1	8.0	.25

* Weights expressed in thirty-seconds of an ounce above or below one pound.

TABLE 2.— EFFECT OF A MEDIUM HIGH TEMPERATURE AND A MEDIUM HIGH HUMIDITY ON LOSS IN WEIGHT OF PRINT BUTTER

Temperature of storage room (degrees Fahrenheit)		59	60	60	61	59	62	63	60	63	63	Average temperature 61	
Humidity of storage room		87	88	89	88	90	89	90	86	87	88	Average humidity 88	
Number of days in storage room		1	2	3	4	5	6	7	8	9	10		
												Total loss	
Position	Number of prints	Weight*										In thirty-seconds of an ounce	In decimals of an ounce
1	13	5.0	3.0	3.0	2.0	1.0	0.5	0.0	—1.0	—2.0	—2.0	7.0	.22
2	13	1.3	0.5	0.0	0.0	—1.5	—2.0	—2.7	—3.5	—3.5	—3.7	5.0	.16
3	13	4.3	3.3	2.4	2.0	0.5	—0.5	—1.6	—2.3	—3.0	—3.1	7.4	.23
4	13	8.0	7.0	6.8	6.0	5.2	4.3	3.3	2.3	2.2	2.0	6.0	.19
5	13	10.4	9.5	9.0	8.3	7.0	6.5	5.5	5.0	4.8	4.5	5.9	.18
6	13	10.3	9.3	9.0	8.7	7.5	7.0	6.5	5.5	5.0	4.2	6.1	.19
7	13	7.3	6.3	5.2	4.7	4.7	4.7	4.7	4.0	3.0	2.5	4.8	.15
8	13	2.0	1.0	0.0	0.0	—1.0	—1.6	—2.3	—3.0	—3.0	—3.5	5.5	.17
9	13	5.5	3.5	4.0	4.0	3.0	2.0	1.8	0.5	1.0	0.5	5.0	.16
10	13	9.0	8.0	7.5	7.3	6.5	5.5	4.5	3.5	3.5	4.0	5.0	.16
Average for 130 prints		6.3	5.1	4.7	4.3	3.3	2.6	2.0	1.1	0.8	0.5	5.8	.18

* Weights expressed in thirty-seconds of an ounce above or below one pound.

TABLE 3.—EFFECT OF A COMPARATIVELY LOW TEMPERATURE AND A HIGH HUMIDITY ON LOSS IN WEIGHT OF PRINT BUTTER

Temperature of storage room (degrees Fahrenheit)........		50	.....	.....	.....	49	.....	.....	50	.....	48	Average temperature 49	
Humidity of storage room..............		93	.....	.....	.....	94	.....	.....	93	.....	95	Average humidity 94	
Number of days in storage room.......		1	2	3	4	5	6	7	8	9	10		
		Weight*										Total loss	
Position	Number of prints											In thirty-seconds of an ounce	In decimals of an ounce
1............	4	10.0	.....	.....	.....	6.0	.....	.....	4.0	.....	9.0	1.0	.03
2............	4	9.0	.....	.....	.....	10.0	.....	.....	9.0	.....	5.0	4.0	.13
3............	4	6.0	.....	.....	.....	7.0	.....	.....	6.0	.....	4.0	2.0	.07
4............	4	6.8	.....	.....	.....	4.6	.....	.....	3.3	.....	4.8	2.0	.07
5............	4	5.0	.....	.....	.....	3.0	.....	.....	1.3	.....	3.0	2.0	.07
6............	4	10.0	.....	.....	.....	8.0	.....	.....	7.0	.....	8.0	2.0	.07
7............	4	9.0	.....	.....	.....	10.0	.....	.....	9.0	.....	8.0	1.0	.03
8............	4	8.5	.....	.....	.....	7.0	.....	.....	6.0	.....	7.0	1.5	.05
9............	4	9.0	.....	.....	.....	11.0	.....	.....	10.0	.....	9.0	0.0	.00
10............	4	2.0	.....	.....	.....	3.0	.....	.....	2.0	.....	0.0	2.0	.07
Average for 40 prints		7.5	.....	.....	.....	7.0	.....	.....	5.8	.....	5.8	1.8	.06

* Weights expressed in thirty-seconds of an ounce above or below one pound.

The conditions on which Table 1 is based are like those that may be found in a creamery refrigerator of very poor type. In fact, the temperature conditions are little better than room temperature. It is seen from the table that with an average temperature of 68° F. and an average humidity of 79 per cent, the average shrinkage on a one-pound print in ten days was 8/32, or .25, of an ounce. This is less than the shortage allowed by the law of New York State, quoted on page 587.

The figures in Table 2 represent conditions that may be found in a creamery refrigerator of medium or rather poor type. With an average temperature of 61° F. and an average humidity of 88 per cent, the shrinkage on a one-pound print in ten days was 5.8/32, or .18, of an ounce. The change from the conditions dealt with in Table 1 to those dealt with in Table 2 represents a change from a room that is practically normal to one that is slightly damp.

The conditions pointed out in Table 3 are those that may be expected in a creamery refrigerator of a better type. With an average temperature of 49° F. and an average humidity of 94 per cent, the shrinkage on a one-pound print in ten days was only 1.8/32, or .06, of an ounce. In this case, however, the temperature was noticeably low (49° F.) and the humidity was very high (94 per cent).

In the light of these three tables, it seems evident that butter should not be kept for any great length of time in the average small

creamery refrigerator. This statement is made under the assumption that the conditions in such small refrigerators are poorer than those represented in Table 3. If butter is kept in a refrigerator where the conditions are as poor as those dealt with in Tables 1 and 2, the shrinkage in ten days will be nearly as much as the shortage allowed by law, not to mention the depreciation in quality.

In Figure 34 the rate of shrinkage under the three types of storage conditions during the ten days is shown graphically. It is seen that the

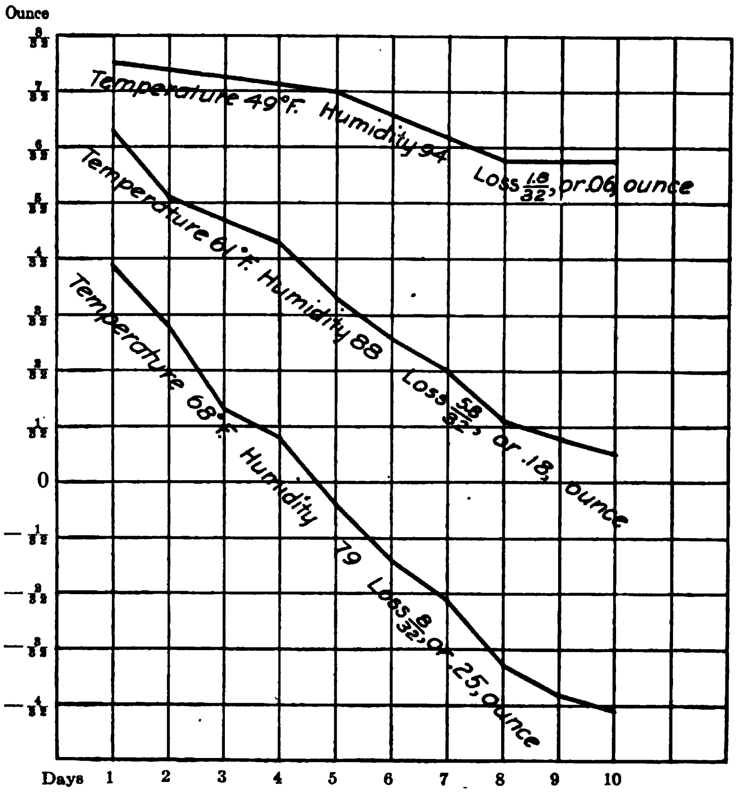

FIG. 34.—*Rate of shrinkage under the three refrigerating conditions considered*

rate of shrinkage is practically uniform except in the latter part of the storage period, when the rate becomes somewhat slower.

The great importance of the temperature of storage places and the humidity of the atmosphere is graphically represented in Figure 35. The lower curve in this figure shows the shrinkage on twenty-five prints that

were set on shelves in a room with an average temperature of 70° F. and an average humidity of 80 per cent. After eight days these prints were transferred to a room with an average temperature of 65° F. and an average humidity of 87 per cent, and were kept there for ten days. After the change to better conditions, not only did the shrinkage cease, but the prints actually gained weight for several days. The upper curve shows the shrinkage on twenty-five prints that were placed on shelves for eight days in a room having an average temperature of 65° F. and an average humidity of 87 per cent, and were then transferred for ten days to a room having an average temperature of 70° F. and an average humidity of 80 per cent. After the change to poorer conditions the rate of evaporation was greatly accelerated.

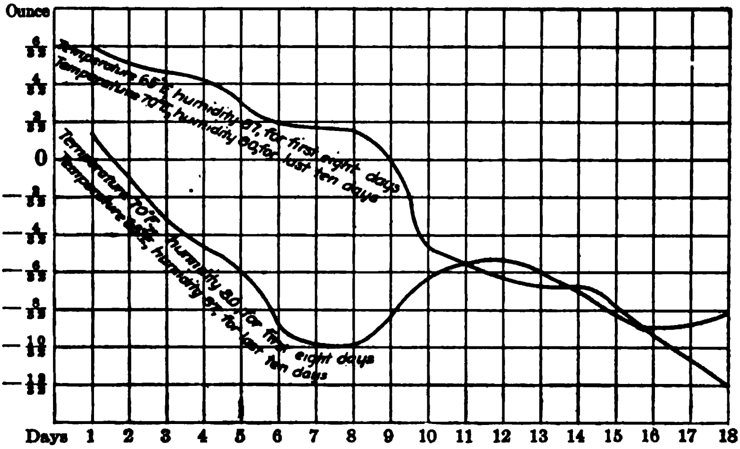

FIG. 35.—*Curves showing the abrupt changes in rate of shrinkage following changes in storage conditions on the eighth day*

As a further indication of the importance of the temperature of storage places and the humidity of the atmosphere, it is shown in Tables 1 and 2 that the average shrinkage of the prints in positions 1, 5, 6, and 10 — those that were most exposed — was greater than that of the six other prints; while the average shrinkage of prints 1, 5, 6, and 10 shown in Table 3 is equal to that of the six others.

Effect of length of time in storage

Usually print butter is held in storage for only a few days or a few weeks, so that these studies would naturally cover a short storage period. Results of experiments on this point are shown in Table 4:

TABLE 4.— EFFECT OF LENGTH OF TIME IN STORAGE ON LOSS IN WEIGHT OF PRINT BUTTER

Temperature of storage room (degrees Fahrenheit)		48	48	Average temperature 48	
Humidity of storage room		94	93	Average humidity 94	
Number of days in storage room		1	24		
Position	Number of prints	Weight*		Total loss: In thirty-seconds of an ounce	Total loss: In decimals of an ounce
1	3	16.0	13.0	3.0	.09
2	3	6.0	2.0	4.0	.13
3	3	4.0	2.0	2.0	.07
4	3	8.0	6.0	2.0	.07
5	3	6.0	2.0	4.0	.13
6	3	11.0	10.0	1.0	.03
7	3	6.0	5.0	1.0	.03
8	3	9.0	4.0	5.0	.16
9	3	9.0	8.0	1.0	.03
10	3	0.0	—3.0	3.0	.09
Average of 30 prints		7.5	4.9	2.6	.08

* Weights expressed in thirty-seconds of an ounce above or below one pound.

The table shows that the average shrinkage on a one-pound print in twenty-four days under good refrigerating conditions for a creamery, was 2.6/32, or .08, of an ounce, which is less than 1/32 of an ounce more than the shrinkage occurring in ten days under essentially the same conditions. This seems to indicate that the rate of shrinkage becomes less as the length of time in storage increases. It is seen also that the average shrinkage on a one-pound print stored for twenty-four days where the temperature was 48° F. and the humidity 94 per cent, was much less than it was during ten days when the temperature was higher and the humidity was lower. Another point to be noted is that the shrinkage under these conditions was 5.4/32, or .17, of an ounce less in twenty-four days than the average amount allowed by the law of New York State. It is probable, then, that the butter manufacturer takes no risk from shrinkage during the time when the butter would ordinarily be in his possession, provided the conditions are as good as those represented in Table 4.

Effect of weight of paper used for wrapping

It has been generally assumed that the weight of paper used for wrapping print butter has a marked effect on the degree of shrinkage. In the study of this question the following conditions and factors were considered: a comparatively high temperature with a comparatively low

humidity; a medium high temperature with a medium high humidity; a comparatively low temperature with a high humidity; length of time in storage; storage in small store refrigerators or show cases. The length of time for this series of experiments was ten days to two weeks. There were ten prints in each box.

TABLE 5.— Effect of Weight of Paper Used for Wrapping on Loss in Weight of Print Butter

		Average shrinkage on ten prints (in thirty-seconds of an ounce)					Average shrinkage on ten prints (in decimals of an ounce)				
Weight of paper*		20	25	30	40	50	20	25	30	40	50
Box	Number of prints										
1	10	5.7	5.0	5.9	6.9	5.0	.18	.16	.18	.22	.16
2	10	2.4	3.8	4.7	4.9	3.5	.07	.12	.15	.15	.11
3	10	3.5	4.1	5.4	5.6	2.7	.11	.13	.17	.18	.08
4	10	2.1	1.7	3.6	3.1	1.6	.07	.05	.11	.10	.05
5	10	4.5	4.1	6.4	6.3	4.7	.14	.13	.20	.20	.14
6	10	6.6	6.8	8.6	8.7	7.6	.21	.21	.27	.27	.24
7	10	5.7	4.2	4.0	4.0	3.3	.18	.13	.13	.13	.10
8	10	4.3	2.9	3.8	3.8	4.1	.13	.09	.12	.12	.13
Average for 80 prints		4.4	4.1	5.3	5.4	4.1	.14	.13	.17	.17	.13

* The quoted weight of parchment paper for wrapping butter is the weight in pounds of 500 sheets 24 by 36 inches in size, which will cut, with some waste, into 4500 butter wrappers 8 by 11 inches.

Apparently, from the results shown in Table 5, the weight of the wrapper has very little to do with the degree of shrinkage. It is true that there are slight variations in the amounts recorded, but these do not show any relation to the weights of wrappers. The degree of shrinkage is not proportional to the weight of paper used, and, moreover, it is very nearly the same, all other things being comparable, no matter what weight of paper is used.

Effect of different methods of packing — in cartons, dry in wrappers, or wet

Before being packed for shipment, print butter is commonly treated in one of three ways: it is either placed in cartons, left in the wrappers without treatment, or sprinkled with water.

In order to determine the relative value of these practices so far as shrinkage is concerned, the following experiments were conducted: Three fifty-pound boxes of print butter were taken from each of six different churnings. The prints in the first of the three boxes were wrapped in ordinary wrappers, placed in cartons, and weighed; those in the second

box were wrapped in paper only, and were weighed; those in the third box were wrapped in paper, weighed, and sprinkled with water. The butter was then stored for ten days in a room representing good refrigerating conditions for a creamery (temperature 49° F., humidity 94 per cent). The results are recorded in Table 6:

TABLE 6.— EFFECT OF DIFFERENT METHODS OF PACKING ON LOSS IN WEIGHT OF PRINT BUTTER

Temperature of storage room (degrees Fahrenheit)		49			49			49			49			Loss		
Humidity of storage room		94			94			94			94					
Number of days in storage room		First day			Third day			Sixth day			Tenth day					
Position	Number of prints	*	†	‡	*	†	‡	*	†	‡	*	†	‡	*	†	‡
1.......	6	11.0	7.0	19.0	10.0	6.0	16.0	9.0	5.0	15.0	9.0	5.0	14.0	2.0	2.0	5.0
2.......	6	9.0	5.0	8.0	8.0	3.0	5.0	8.0	3.0	4.0	8.0	2.0	4.0	1.0	3.0	4.0
3.......	6	18.0	8.0	15.0	16.0	6.0	14.0	16.0	6.0	12.0	15.0	4.0	11.0	3.0	4.0	4.0
4.......	6	16.0	7.0	15.0	14.0	6.0	12.0	13.0	5.0	11.0	12.0	4.0	11.0	4.0	3.0	4.0
5.......	6	17.0	—4.0	15.0	16.0	—5.0	12.0	16.0	—6.0	11.0	15.0	—7.0	10.0	2.0	3.0	5.0
6.......	6	12.0	18.0	8.0	12.0	13.0	8.0	9.0	12.0	8.0	8.0	11.0	6.0	4.0	7.0	2.0
7.......	6	18.0	0.0	3.0	18.0	—2.0	2.0	18.0	—3.0	1.0	16.0	—3.0	—1.0	2.0	3.0	4.0
8.......	6	12.0	1.0	5.0	11.0	0.0	4.0	10.0	—1.0	3.0	9.0	—2.0	2.0	3.0	3.0	3.0
9.......	6	22.0	14.0	10.0	21.0	12.0	12.0	21.0	11.0	10.0	21.0	9.0	9.0	1.0	5.0	1 0
10.......	6	12.0	6.0	9.0	11.0	3.0	9.0	10.0	2.0	8.0	10.0	2.0	8.0	2.0	4.0	1.0
Average for 60 prints..........		14.7	6.2	10.7	13.7	4.2	9.4	13.0	3.4	8.3	12.3	2.5	7.4	2.4	3.7	3.3

* Average weight (in thirty-seconds of an ounce above or below one pound) of the six prints in each position on the first, third, sixth, and tenth days when wrapped in paper and packed in cartons.
† Average weight (in thirty-seconds of an ounce above or below one pound) of the six prints in each position on the first, third, sixth, and tenth days when wrapped in paper.
‡ Average weight (in thirty-seconds of an ounce above or below one pound) of the six prints in each position on the first, third, sixth, and tenth days when wrapped in paper and sprinkled with water.

According to Table 6, the average shrinkage on a one-pound print of butter packed in a carton was found to be 2.4/32, or .075, of an ounce; the shrinkage on a pound of butter packed dry was found to be 3.7/32, or .116, of an ounce; the shrinkage when the butter was sprinkled with water was 3.3/32, or .103, of an ounce. The results of these experiments indicate that sprinkling the prints with water just after packing them in boxes has very little effect in preventing shrinkage, while packing the prints in cartons tends to decrease the shrinkage considerably.

Effect of keeping butter on shelves during storage

A large proportion of print butter lies on the shelf for a certain length of time. Therefore a study was made of the evaporation taking place during this part of the process of marketing butter. In this experiment fifty prints were placed on shelves in the refrigerator of the departmental salesroom, in piles of ten. The results are shown in Table 7:

TABLE 7.— Effect of Storage in Small Store Refrigerators or Show Cases, When the Individual Prints are Set on Shelves

Days	1	2	3	4	5	6	7	8	9	10	Total loss
Weights*	14.4	....	12.0	....	11.2	....	....	8.8	....	7.4	7.0

* Average weight of fifty prints on the days noted, expressed in thirty-seconds of an ounce above or below one pound.

It is seen from this table that the average shrinkage in ten days under such conditions as are often found in show cases and small refrigerators of the store type, is practically as much as the law permits. If the butter is held no longer than three or four days, however, it seems that the loss is not likely to approach the limit set by law.

SUMMARY

1. The variation of pore space, which ranges from .5 of 1 per cent to over 6 per cent in freshly made butter, is important in the printing process.

2. Print butter gradually loses weight in storage.

3. The rate of loss depends principally on the temperature and humidity of the storage room.

4. If the temperature is kept down to 50° F. and the humidity is kept above 90 per cent, at least a month, and perhaps much longer, will be required for the shrinkage to approximate the limit set by law, provided the prints are packed in boxes.

5. If the temperature is 60° F. or above, and the humidity is 85 per cent or below, the shrinkage will approximate the limit set by law in a space of ten days to two weeks, even if the prints are packed in boxes.

6. The degree of shrinkage is not inversely proportional to the weight of the wrapper used, as is generally supposed.

7. The degree of shrinkage decreases to a considerable extent when the prints are placed in cartons. The other two methods of packing, however — leaving the prints dry after placing them in boxes, or sprinkling them with water — produce about the same effect on the degree of shrinkage.

8. In the average small store refrigerator, the loss will approximate the limit set by law in a space of ten days when the prints are piled loosely on shelves.

Submitted for publication December 3, 1914.

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THE CONTROL OF APPLE INSECTS IN CLINTON COUNTY

By C. R. CROSBY and A. J. MIX

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THE CONTROL OF APPLE INSECTS IN CLINTON COUNTY

C. R. CROSBY AND A. J. MIX

It is the purpose of the writers to discuss in this bulletin the insects that cause greatest injury to apples in Clinton County. Four years ago, when the writers first took up the study of the insect problems of that section, they were immediately convinced that owing to location and climate it would be necessary to modify the system of spraying usually employed in western New York, to fit local conditions. Although this bulletin is primarily intended to give practical directions for the control of orchard insects, nevertheless it is considered advisable to state the fundamental facts in the life history of each insect in order that there may be an intelligent understanding of the reasons for each operation. Conditions vary so greatly from season to season that it is impossible to devise any set of spraying rules to be followed blindly; the grower should become familiar with the insect enemies of his orchard, so that he may adapt his spraying operations to the peculiar needs of the season. The junior author has spent the last two seasons in Clinton County, studying the problems that confront the fruit grower in the control of insect pests and plant diseases. This work was made possible by the establishment of an industrial fellowship in the New York State College of Agriculture by the Champlain Valley Fruit Growers' Association.

CODLING MOTH (*Carpocapsa pomonella* Linnæus)

The codling-moth caterpillar is the insect that causes the great proportion of wormy apples, and it is the most serious insect pest with which fruit growers in northern New York have to contend. In unsprayed orchards it causes a loss of twenty-five to fifty per cent of the crop. According to the census of 1910, there were 24,564 barrels of apples raised in Clinton County. Assuming that one-fourth of the crop was destroyed by the codling moth, the production that year should have been 32,752 barrels; thus the loss was 8188 barrels. Estimating the value of these apples at one dollar a barrel, the loss would be $8188. According to the same census there were 147,313 bearing trees in Clinton County. It is estimated that twenty per cent of these trees are sprayed at least once for the codling moth. The cost of this work is not far from ten cents a tree, or $2946.20. The sum of the loss of the fruit and the cost of spraying necessitated by the codling moth is $11,134, which represents the annual tax levied on Clinton County by this insect.

The codling moth passes the winter as a full-grown caterpillar in a slight silken cocoon, under flakes of bark and in crevices on the trunk and the larger branches of trees. With the advent of warm weather in the spring, the caterpillar transforms inside its cocoon to a brownish pupa about one-half inch in length (Fig. 36). In a little less than a month the mature insect, or moth, emerges. The moth (Fig. 37) has an expanse of about three-fourths of an inch. The front wings have the general appearance of watered silk, and are marked near the tip with a light brown spot bounded on the inside by a chocolate band. The moths are rarely seen in the orchard, for their dull colors harmonize perfectly with the gray bark of the branches on which they rest during the daytime. They fly mostly in the dusk of the evening.

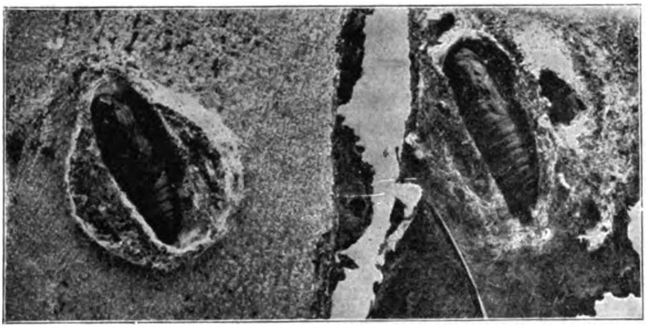


FIG. 36.— *Pupæ of codling moth, in their cocoons. Enlarged*

FIG. 37.— *Codling moth, enlarged*

The moths continue to emerge during a period of several weeks, but the greatest number appear about two weeks after the petals fall. If the weather is warm the moths begin to lay eggs in four or five days; but if the weather is cool or stormy, egg laying may be deferred for a considerable period. The female moth deposits her flat, disk-shaped, scale-like eggs, about one-twenty-fifth inch in diameter, on the leaves and skin of the fruit, not in the blossom end of the apple (Fig. 38). As the moths emerge during a considerable period, egg laying also continues for several weeks, but the greater part of the eggs are laid

FIG. 38.— *Codling-moth egg, greatly enlarged*

about three weeks after the petals fall. The eggs hatch in a week or ten days. On hatching, the young caterpillar, which is about one-sixteenth inch in length, may feed slightly on the foliage before reaching the fruit.

FIG. 39.— *Full-grown codling-moth caterpillar in its burrow in an apple*

Most of the caterpillars enter the fruit at the blossom end. A few enter at the stem end or at the side, where two fruits touch. Most of them enter the fruit about three weeks after the petals fall. The caterpillar burrows directly to the core, devours the seeds, and, when nearly full-grown, tunnels out to the surface, usually at the side of the apple, leaving its burrow practically filled with a mass of excrement (Fig. 39). The time spent by the caterpillar in the apple averages about one month.

When full-grown, the caterpillar leaves the apple, crawls to the trunk or the larger branches, and there in some protected crevice forms a silken cocoon. Observations of the last two years in Clinton County indicate

FIG. 40.— *Two apples in perfect condition for spraying. The petals have just fallen. Note that the calyx lobes are widely spread*

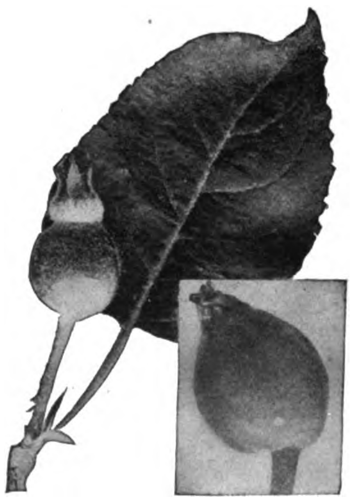


FIG. 41.—*Too late to spray effectively. Note that the calyx lobes are nearly together.*

Egg of codling moth on young apple

that as a rule these caterpillars do not transform to moths until the following spring, and that the second brood of caterpillars is therefore unim-

portant in that region. In western New York, however, some of the caterpillars spinning cocoons before the first of August may transform in the same season, thus producing a second brood of moths.

Means of control

The most important spray for the control of the codling moth should be applied just as the last of the petals are falling. This spray consists of 6 pounds of arsenate of lead, 2½ gallons of lime-sulfur, and water to make

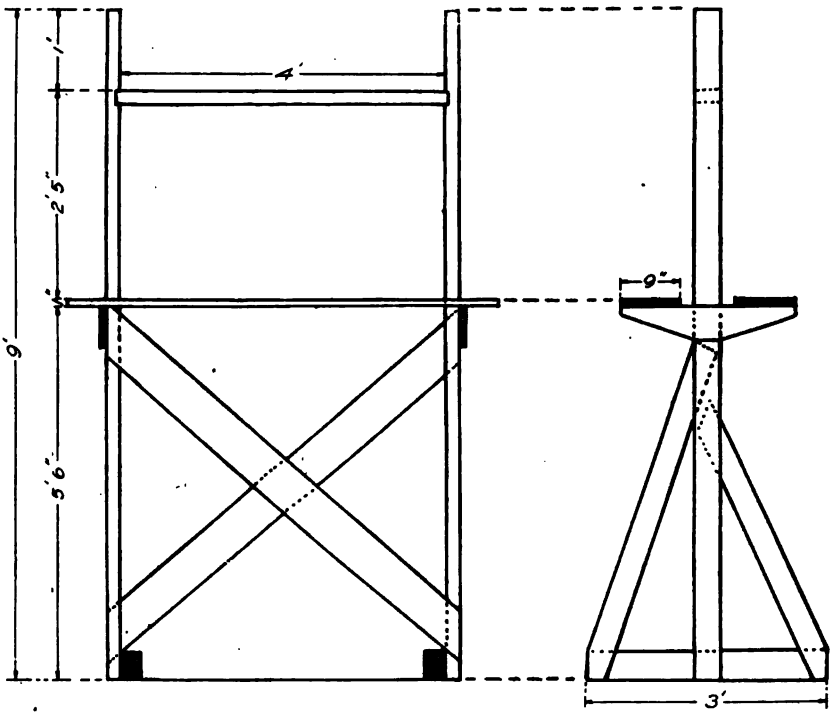


FIG. 42.— *Working drawing of a cheap but serviceable spraying tower*

100 gallons. The lime-sulfur has no effect on the codling moth, but is used for the control of apple scab. At this time the calyx lobes at the blossom end of the apple are expanded (Fig. 40), and it is possible to drive the poison down into the calyx cavity. In a few days the calyx lobes close over this cavity and this prevents the washing away of the poison by rain (Fig. 41). The majority of the young caterpillars enter the fruit by the blossom end, and will be poisoned in the calyx cavity before they can injure the fruit.

In order to be effective it is important that the spray be directed down-

ward into the ends of the young apples, and that sufficient force be used to drive it into the calyx cavity. Good results cannot be obtained by spraying from the ground, or, in the case of large trees, by a man standing in a wagon box. A tower should be used, high enough so that by the use of an extension rod and an angle nozzle it will be possible to reach out over the tree and direct the spray downward into the ends of the young fruits. Spraying upward into a tree and letting the spray fall down into the top is a waste of time and material as far as control of codling moth is concerned. Spraying so that a cluster is hit on the side instead of at the end is ineffectual, since the force of the spray pushes the cluster over and no material enters the calyx cavity. The young apples that hang so that they are hit squarely in the end by a sidewise spray are the ones that fall later; it is the center apples of a cluster that develop to maturity.

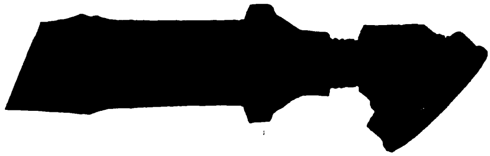


FIG. 43.— *An angle nozzle attached to a bamboo extension rod*

A satisfactory inexpensive tower, which can be easily built from materials usually found around the farm, is shown in Figure 42. The front and rear posts and saddle rails are made of 2x4-inch material; the footboards should be 1x9-inch oak boards; the supports for the footboards and the side and end braces may be inch boards of any description. The bottom crosspieces are preferably made of 3x4-inch material, but 2x4-inch pieces may be used if necessary. The dimensions of the tower are given in the accompanying figure and may be varied to meet individual requirements. Such a tower can be chained into a wagon box or fastened to the top of the spray tank and removed when not in use. It is easy to ride; the rail is gripped by the operator's knees, leaving the hands free for spraying. Wherever it has been used it has given entire satisfaction.

FIG. 44.— *An angle double-ball shut-off attached to the base of an extension rod and connected with a hose leading to the pump. This type of shut-off will not leak, and is very easily turned on and off. The hose is attached at an angle, and therefore does not kink nor break; also, the rod is easy to hold*

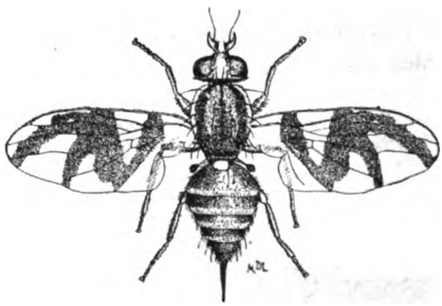
The best type of angle nozzle to use is one in which the bend is in the nozzle itself. not in the pipe back of the nozzle (Fig. 43); in such an arrange-

ment as the latter, the pipe catches on the branches and this interferes with rapid work. The nozzle should be attached to the end of a 10-foot bamboo extension rod, which is provided with a shut-off. A very convenient type of shut-off is the angle double-ball shut-off shown in Figure 44. This may be closed or opened by merely pressing with the thumb, and does not leak when closed — a common fault of most shut-offs.

The second application is made three weeks after the petals have fallen, because at that time the codling-moth caterpillars are beginning to hatch and to enter the fruit.

APPLE MAGGOT (*Rhagoletis pomonella* Walsh)

In Clinton County the apple maggot is frequently known as the railroad worm. It is especially destructive to Tolman, Fameuse, and McIntosh apples. The small white maggots tunnel through the flesh of the fruits, rendering them unfit for food, and often cause the growers serious financial loss.



DRAWN BY M. D. LEONARD

FIG. 45.— *Female apple maggot fly*

The parent flies are slightly smaller than the house fly and have the wings crossed by three dark bands (Fig. 45). The flies appear in the latter part of June or the first of July, and may be seen resting on the fruit and foliage. Their mouth parts are adapted for lapping fluids. They feed on drops of moisture and on the bloom of the fruit, which they first dissolve with a drop of saliva. After feeding for two or three weeks the female begins laying, which is continued throughout the summer. She inserts her minute white eggs in the flesh of the apple through a puncture in the skin (Fig. 46). The eggs hatch in from two to six days and the larvæ burrow through the flesh of the fruit (Fig. 47). If the flesh is hard the maggots grow very slowly and are difficult to find before the fruit begins to ripen or to soften from decay.

FIG. 46.—*Egg of apple maggot inserted in the flesh of an apple just beneath the skin. Greatly enlarged*

When full-grown the maggot (Fig. 48) emerges from the fruit through a ragged hole in the skin, burrows into the ground an inch or so, and there within the thickened and hardened skin, known as the puparium (Fig. 49), transforms to a delicate whitish pupa, in which condition the insect remains until the following spring.

Means of control

In orchards that have been seriously infested in previous years, two or three applications of sweetened arsenate of lead should be made

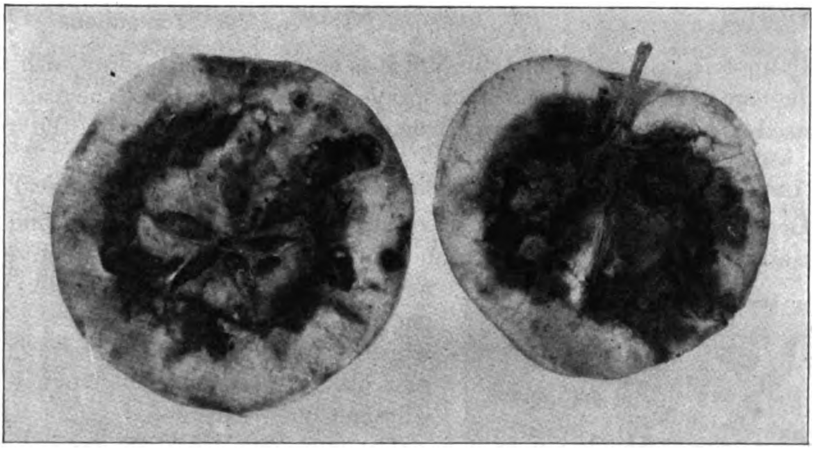


FIG. 47.— *Apples infested by apple maggots, cut open in order to show decaying interior*

at intervals of two weeks, beginning about the first of July. In orchards that have not been previously infested, special applications of sweetened spray are unnecessary. In well-cultivated orchards, where conditions are unfavorable for hibernation of the puparia, the pest is ordinarily held in check by the regular system of spraying in use for the control of

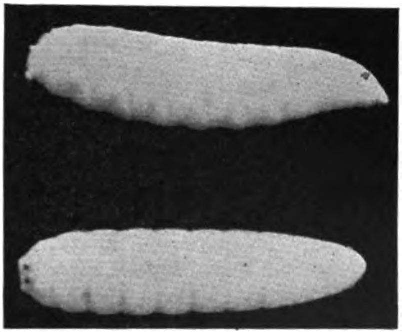


FIG. 48.— *Lateral and dorsal view of full-grown apple maggots*

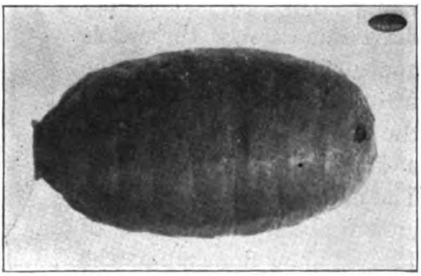


FIG. 49.— *Puparium of apple maggot, enlarged. Natural size shown in upper right corner*

the codling moth, the last application being made three weeks after the petals fall. The sweetened spray is much less adhesive than the unsweetened

spray, and when it is used it is necessary to repeat the application after each rain. The formula most commonly used for the sweetened spray is:

Arsenate of lead	6 pounds
Molasses	2 gallons
Water	100 gallons

In applying the sweetened mixture it is not necessary to spray with the same care as in applying the other sprays, because in this case the material is used as a bait. The flies are attracted to it from other parts of the tree.

GREEN FRUIT-WORMS (*Xylina antennata* Walker, and other species)

Green fruit-worms are large, greenish, light-striped caterpillars, one to one and one-half inches in length, and in some years are very destructive to apples and other fruits. Outbreaks occur at intervals of several years, during which the pest is almost unknown. The pest has been especially destructive in Clinton County during 1913 and 1914.

FIG. 50.— *Moth of green fruit-worm*

The mottled gray moths (Fig. 50) appear in the orchard early in the spring, in March or April, and deposit their eggs singly on the branches of the trees. The eggs hatch just as the buds are opening; the young caterpillars feed on the opening leaves and become about half-grown when the fruit sets. They do not burrow into the fruit, but eat out large cavities, sometimes devouring nearly the whole apple (Fig. 51). When the fruit is not too badly injured, the wound heals over, leaving a large, rough, corky scar. The caterpillars become full-grown about the middle of June. They descend to the ground, and a few inches below the surface transform to brownish pupæ in earthen cells which are usually lined with a slight silken cocoon. Most of the moths emerge in September and hibernate in sheltered places, but a few do not emerge until the following spring.

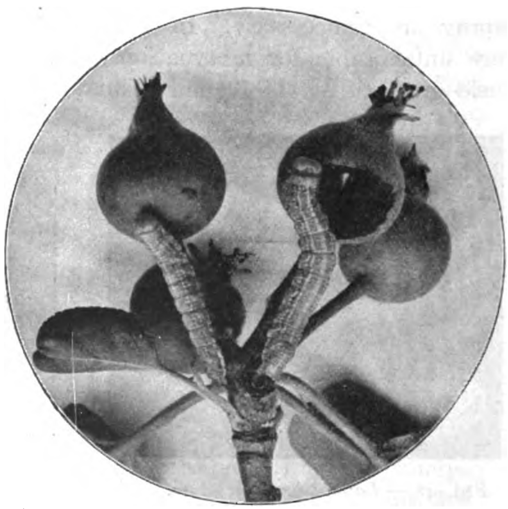
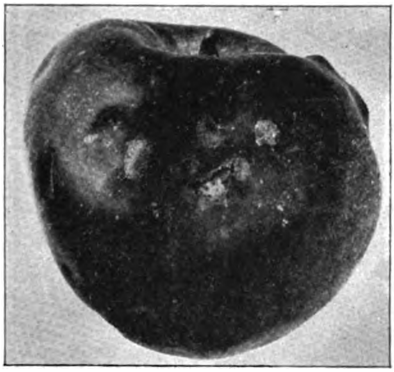


FIG. 51.— *Green fruit-worms feeding on young apples*

Means of control

By the time the caterpillars attack the young fruits they are nearly full-grown, and it is then too late to kill them with poison sprays. Caterpillars of this size are very resistant to poisons, and furthermore the greater part of their food consists of the flesh of the fruit, which it is impossible to poison. Effective work can be done, however, by very thorough applications of arsenate of lead, 6 to 8 pounds to 100 gallons of spray solution, made just before the blossom cluster separates. Success in fighting green fruit-worms cannot be expected unless the work is done with great thoroughness.

FIG. 52.— *Beetle of plum curculio. Enlarged*



PHOTOGRAPH BY H. H. KNIGHT

FIG. 53.— *Apple scarred by egg-laying punctures of the plum curculio*

PLUM CURCULIO (*Conotrachelus nenuphar* Herbst)

In some orchards the fruit is likely to be badly scarred by the feeding and egg-laying punctures of the plum curculio (Figs. 52 and 53). This injury is always severest in neglected orchards. The curculios hibernate in hedges, stone walls, and stone piles, and the first step in their control is the elimination of such shelters. A rank growth of grass or weeds in an orchard also tends to increase injury from curculio. Well-cultivated orchards are less subject to attack. Curculio injury is also greater in trees with bushy, unpruned tops.

Under favorable conditions, where the trees are properly pruned and the orchards are well cultivated, and where stone walls, stone piles, and hedgerows are not allowed in the vicinity of the orchard, the plum curculio can be controlled by the regular system of spraying employed for the control of the codling moth.

FIG. 54.— *Apple injured by a bud-moth caterpillar in late summer*

BUD MOTH (*Tmetocera ocellana* Schiffermüller)

The bud moth is a common and troublesome pest in Clinton County orchards. The small, brown, black-headed, half-grown caterpillars hibernate in obscure bark-colored cocoons hidden

away in the angles of the apple twigs. The caterpillars leave their winter quarters just as the buds are bursting, burrow into the opening buds, and feed on the expanding leaves. They often web two or three leaves together, and often include several blossoms in the nest thus formed. They may therefore nip in the bud a considerable part of the future crop. When full-grown the caterpillars pupate in this nest of webbed leaves, and the moths emerge during June and the first part of July and deposit their eggs in small clusters on the leaves. The eggs hatch in a week or ten days, and the young caterpillars feed on the underside of the leaves in a small silken tube open at both ends. When a leaf touches an apple the caterpillars often make a number of small holes in the surface of the fruit, thus causing blemishes which may greatly

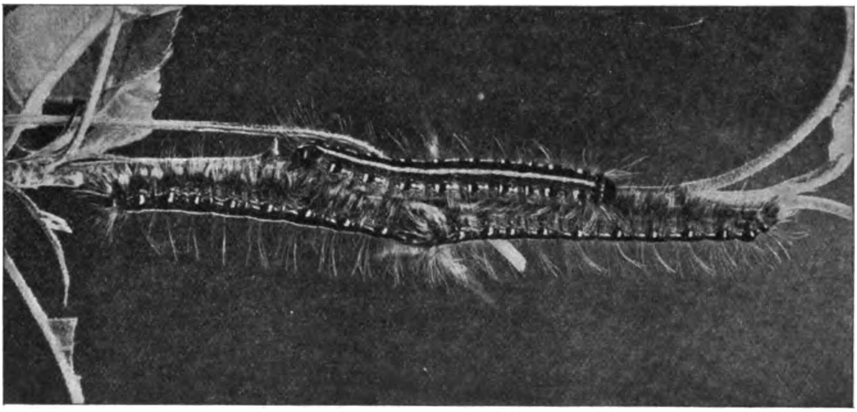


FIG. 55.— *Full-grown apple tent-caterpillars*

decrease the value of the crop (Fig. 54). The caterpillars become about half-grown by the end of the season, and go into winter quarters in little cocoons on the branches.

Means of control

Experiments have shown that it is not practicable to destroy the caterpillars in their winter quarters by dormant sprays. Effective work against this insect can be done, however, by thorough application of arsenate of lead, 6 pounds to 100 gallons of water or dilute lime-sulfur, when the blossoms show pink. This coincides with the first application for the control of apple scab. This one spraying, alone, will not kill all the caterpillars, but if made in conjunction with the regular system of spraying for the codling moth, and continued over a period of several years, it will so reduce their number as to render them a negligible factor in the orchard.

APPLE-TREE TENT-CATERPILLAR (*Malacosoma americana* Fabricius)

During the past two years the orchards in Clinton County have been devastated by tent caterpillars belonging to this and the following species. The apple-tree tent-caterpillars can be distinguished from the forest tent-caterpillars by the continuous light stripe down the back, instead of a row of wedge-shaped spots (Fig. 55).

The apple-tree tent-caterpillar feeds on apple, wild cherry, witch-hazel, beech, birch, barberry, oak, willow, and poplar, but it breeds most abundantly on wild cherry. The winter is passed in the egg stage. The eggs are deposited in masses of three to four hundred, usually encircling a twig as a broad band (Fig. 56). Each mass is protected by a brownish, gluey froth. The eggs hatch in the spring, just as the buds begin to show green. The caterpillars from each egg mass live in colonies, forming large, unsightly silken nests on the branches. In some cases caterpillars from two or more egg masses unite to form a single nest. When the caterpillars are abundant they often defoliate the trees, and thus not only destroy the crop of the season but so weaken the tree that it is unable to set fruit buds for the following year.

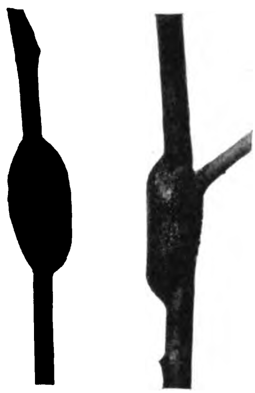


FIG. 56.— *Egg masses of apple tent-caterpillar*

The caterpillars become full-grown about the first of June and spin white silken cocoons under any convenient shelter. The moths emerge in about three weeks and lay their eggs in July. There is only one generation a year.

Means of control

Care should be taken, when trimming the orchard, to cut out and burn all twigs bearing egg masses. If these are thrown on the ground, as is often done, the eggs will later hatch and the caterpillars may find their way to the trees. On small trees it is practicable to rub out the nests with the hands, using an old pair of gloves, when the nests are very small. Burning out the nests with a torch, another common practice, is injurious to the tree; the common apple-tree cankers often develop in spots scorched by the torch. In commercial orchards the caterpillars may be satisfactorily controlled by early spraying. In the past two years in Clinton County, it has been found that the dormant lime-sulfur spray as applied for oyster-shell scale, if made when the bud tips show green, will kill nearly all the young caterpillars. When this spraying is omitted, the

second spraying, with arsenate of lead, made just as the blossoms show pink, is very effective. Later sprayings are ineffective, since it is very difficult to poison the caterpillars when they are large.

FOREST TENT-CATERPILLAR (*Malacosoma disstria* Hübner)

For the last two years the forest tent-caterpillar (Fig. 57) has been abundant throughout Clinton County, more especially so from Plattsburg northward. Many neglected orchards are in a dying condition from the attacks of this insect. The forest tent-caterpillar is naturally a forest insect, its favorite food plant being the maple; but it attacks also apple, plum, cherry, and pear. Its life history is very similar to that of the apple-tree tent-caterpillar, but the caterpillars do not form silken nests, and most of the cocoons are found in curled leaves on the trees.

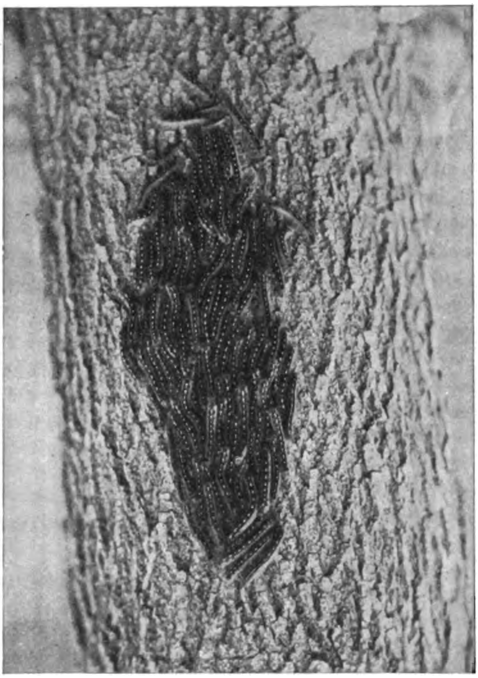


FIG. 57.— *A colony of forest tent-caterpillars resting on a tree trunk*

This insect may be controlled on apple trees by the means suggested for the apple-tree tent-caterpillar, with the obvious exception of wiping out the nests.

OYSTER-SHELL SCALE (*Lepidosaphes ulmi* Linnæus)

The oyster-shell scale is the only important scale insect found in the orchards of Clinton County. It is most injurious to young trees, stunting, and in extreme cases killing, them; old trees suffer less, but are often badly infested.

The insect passes the winter in the egg stage. From thirty to one hundred minute white eggs may be found under each old scale from September until the last of May. The eggs hatch about the last of May or the first of June. The minute, pale yellowish, young insect crawls about over the bark for a few hours and then settles down, inserts its needle-like sucking tube into the bark, and feeds on the sap. The scale-like covering is soon formed and the insect remains in one place for the remainder of its life (Fig. 58). Eggs are laid under the scale in August and September, and the

insect soon dies. Only the eggs are alive during the winter months. There is only one generation a year in this region.

Means of control

The oyster-shell scale may be controlled by thorough spraying with lime-sulfur, 1 part to 8 parts of water, the application being made when the buds begin to show the green tips of the leaves. The application should be repeated every year until the scale ceases to be injurious. Summer applications of lime-sulfur as applied for apple scab are thought to have a tendency to prevent the setting of the young scale.

FIG. 58.— *Oyster-shell scale. Section of a severely infested branch*

PLANT LICE

There are three species of plant lice injurious to the leaves and fruit of the apple in Clinton County. All these forms hibernate as small, oval, black, shiny eggs on the branches of the trees.

Grain aphis, or apple bud-aphis (*Siphocoryne avenæ* Fabricius).—The grain aphids are small, greenish lice, which often appear in countless numbers on the opening buds, but rarely cause any serious injury to apple trees owing to the fact that only one generation is spent on the apple. Most of the second generation develop wings and fly to grains and grasses, where they breed through the remainder of the season. The grain aphis is distinguished from other plant lice infesting the apple by three stripes of darker green running lengthwise of the body.

Apple leaf-aphis, or green aphis (*Aphis pomi* DeGeer).— The apple leaf-aphis usually appears on the trees at the same time as does the grain aphis discussed above; it continues to breed on the apple throughout the summer, however, and is therefore capable of causing much greater injury. It causes the leaves to curl, stunts the growth of the tree, dwarfs the apples, and prevents the normal June drop, thus producing what is known as clustering. Apples injured by aphis attack are small and deformed, and show a characteristic puckering of the blossom end (Fig. 59). This plant louse is also very destructive to young trees, which are sometimes killed outright. The apple leaf-aphis is often aided in its destructive work by the rosy aphis.

Rosy apple aphis (*Aphis sorbi* Kaltenbach).— The rosy apple aphis is often found on apple trees in company with the apple leaf-aphis. These plant lice are thinly covered with a whitish waxy bloom, and the winged

forms are of a pinkish or rosy color; hence the name rosy aphis. They appear on the buds at about the same time as does the apple leaf-aphis, but as a rule only three generations develop on the apple. After the third generation the remainder of the season is spent on broad-leaved and narrow-leaved plantain. Although the lice remain on the apple for only about two months, they are capable of doing great damage. They curl the leaves more severely than does the apple leaf-aphis, and are equally destructive to the fruit.

Means of control.— Plant lice can be fought most effectively by thorough spraying with "black leaf 40" tobacco extract, $\frac{3}{4}$ pint in 100 gallons of water or dilute lime-sulfur solution, the application being made when the lice are clustered on the opening buds. As the spray kills only by contact, very thorough work is necessary and care should be taken to hit all the plant lice with the spray. After the aphids have curled the leaves it is very difficult to hit them, and it is very doubtful whether spraying at that time is worth the trouble involved. In the case of small trees it is better to dip the infested branches in the solution wherever this can be done without breaking the trees.

FIG. 59.— *Apples stunted and deformed as the result of aphis injury*

WOOLLY APHIS (*Schizoneura lanigera* Hausmann)

Woolly aphids are small, reddish brown, plant lice which are found in colonies on the trunks and branches, and also on the roots, of apple trees. As the lice are covered by a woolly mass of long, white, waxy fibers, these colonies are very conspicuous. In Clinton County these lice are most injurious when found in cankers and wounds, where they feed in colonies on the callus and prevent proper healing. Such wounds should be carefully cleaned out and painted with gas tar.

GRASSHOPPERS (*Melanoplus femur-rubrum* DeGeer)

During the past two seasons grasshoppers have been very destructive to a few young orchards located on the light sandy soils of Clinton County. In extreme cases they have completely defoliated the trees, and even girdled the trunk and branches.

Means of control

Grasshoppers may be controlled by the use of poison bait. The formula used by Professor G. A. Dean, of Kansas, is as follows:

Bran	20 pounds
Paris green	1 pound
Sirup	2 quarts
Oranges or lemons	3 fruits
Water	3½ gallons

The bran and the paris green, dry, are mixed thoroughly in a washtub. The juice of the oranges or lemons is squeezed into the water; the remaining pulp and peel is chopped into fine bits and added to the water. The sirup is dissolved in the water and the bran and poison are wet with the mixture, being stirred at the same time so as to dampen the mash thoroughly.

This bait should be spread over five acres of the infested area. It should be sown broadcast very thinly, in order to make it impossible for birds, fowls, and domestic animals to obtain enough poison to kill them. Very little of the bait is eaten after it becomes dry; hence it is important to scatter it in the early morning, just as the grasshoppers are becoming active. A very small quantity of the poison, if eaten, is sufficient to kill the grasshoppers.

SPRAYING SCHEDULE FOR APPLES

Dormant spray, *as the leaf buds begin to show green*

Lime-sulfur (32° Baumé) diluted 1 to 8, for oyster-shell scale and blister mite. To control plant lice, add ¾ pint "black leaf 40" tobacco extract to each 100 gallons. Make the application when the lice are clustered on the opening buds.

Summer sprays

A. As the blossom buds begin to show pink

Lime-sulfur (32° Baumé) diluted 1 to 40, for apple scab; add arsenate of lead, 6 pounds to 100 gallons, for bud moth and green fruit-worm.

B. As the last of the petals are falling

Lime-sulfur (32° Baumé) diluted 1 to 40, for apple scab; add arsenate of lead, 6 pounds to 100 gallons, for codling moth.

This is the most important spray for the control of the codling moth, and the work should be done thoroughly.

C. Three weeks after the petals fall

Lime-sulfur (32° Baumé) diluted 1 to 40, for apple scab; add arsenate of lead, 6 pounds to 100 gallons, for codling moth.

D. Last week in July

Lime-sulfur (32° Baumé) diluted 1 to 40, for apple scab.

Spray for apple maggot, first week in July

Arsenate of lead, 6 pounds to 100 gallons of water and 2 gallons of molasses. Repeat every two weeks or after each rain, until the middle of August.

Spray for plant lice, when the lice are clustered on the opening buds

"Black leaf 40" tobacco extract, ¾ pint to 100 gallons of water or dilute lime-sulfur; if used in water add five pounds of soap to each 100 gallons.

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AGRICULTURAL EXPERIMENT STATION OF

THE COLLEGE OF AGRICULTURE

Department of Animal Husbandry

In cooperation with the Jefferson County Farm Bureau

THE COST OF MILK PRODUCTION

By H. A. HOPPER,
Extension Professor of Animal Husbandry
AND
F. E. ROBERTSON,
Manager, Jefferson County Farm Bureau

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THE COST OF MILK PRODUCTION

H. A. Hopper and F. E. Robertson

A growing demand for more comprehensive information on the cost of producing milk, as compared with its selling price, comes from producer and consumer alike. One county of New York State, Jefferson County, has been studied with respect to this matter, and the results are here presented as having a bearing on conditions throughout the State.

Jefferson County is one of the leading agricultural counties in New York State. Not only is it productive of cereal, forage, and other crops in abundance, but also it stands high in the number of dairy cows maintained within its borders, ranking third in the State in the year 1909, with 64,855 cows. In this respect it is surpassed only by St. Lawrence and Delaware Counties, and exceeds such counties as Oneida, Onondaga, and Chenango, which are conspicuous as centers of the dairy industry. In many ways Jefferson County merits consideration in the study of problems concerned with the business of milk production. It also holds an important commercial position in the dairy business of northern New York, as its county seat, Watertown, has the largest inland cheese board in the world.

By far the greater part of the milk produced in Jefferson County is manufactured into cheese, although within recent years the production of market milk has increased rapidly. The making of cheese began on the farms in 1834, and later it was carried on in cooperative cheese factories. In 1908 there were eighteen butter factories, twenty-two milk shipping stations, and one hundred and twenty-two cheese factories in operation in the county. Most of the cheese is of the usual cheddar type, but nearly all kinds are produced to some extent. The cheese output in 1908 was over fifteen million pounds. During the past fifteen years the market milk interests have developed most rapidly in districts adjacent to the railroads, the annual output of milk now aggregating twelve million quarts.[1]

Only within recent years has it been possible to study in a careful and conclusive manner the question of costs incident to milk production on farms where the business is conducted on a commercial scale. Much experimental data and numerous isolated records of cost are at hand,[2] but as yet there is no adequate amount of carefully prepared data obtained from the herds of practical dairymen in such a manner as to show

[1] New York State Census Report for 1910.

[2] New Jersey Agr. Exp. Sta. Rept. 30:73–76. 1909.
Records of a dairy herd for five years. By J. M. Trueman. Connecticut (Storrs) Agr. Exp. Sta. Bul. 73:127–148. 1912.
Cost of milk production. By Fred Rasmussen. New Hampshire Agr. Exp. Sta. Extension bul. 2:1–20. 1913.

the individual items of food costs, labor costs, and incidental, or fixed, costs, and the proportion that each shares in the production of one hundred pounds of milk or one pound of butter-fat.

Every farm enterprise, if properly studied, will supply valuable information concerning the relationship of the factors involved in its successful management. Much progress can be made, however, by further simplifying methods of record keeping and adapting them to the problem in hand, which will encourage individuals to prosecute the work effectively.

In order to conduct his business successfully, the milk producer must be able to deal intelligently with its technical and commercial features. Some of these are within his control, others are obviously beyond it. On one side he sees forces at work demanding a better product; on the other he sees a constantly ascending scale of costs in terms of labor, feed, and investments. But seldom does he feel that there is a commensurate increase in the selling price of the product to balance the account. The milk producer with good cows properly fed and handled is entitled to a reasonable return for his labor above all legitimate costs involved. Therefore data are needed from many sources to establish the relationship of these cost factors to one another.

The organization of a farm bureau in Jefferson County in April, 1912, made it possible to obtain the data presented in this bulletin. The manager of the farm bureau, as soon as he was appointed, proceeded immediately to organize cow-testing associations on the cooperative basis usually followed throughout the State. In all, three associations have been formed, comprising fifty-three herds well distributed over the county. The yearly records of the 834 cows in these herds have been made the basis of the present study.[3] The information gained should be especially valuable to Jefferson County dairymen, and should also be an incentive to milk producers in general to look more closely to the costs concerned in milk production.

DAIRY CONDITIONS IN JEFFERSON COUNTY

By reason of its climate, topography, soils, and transportation facilities, Jefferson County is naturally endowed with superior advantages as a dairy county. The common grasses, cereals, and legumes for hay produce large yields, and the growing use of and success with alfalfa and vetch are important factors tending to reduce the cost of dairy products in the county.

Root crops for stock are not widely grown, but most dairy farms are equipped with one or more large silos which are filled each year from a practically unfailing corn crop. To supplement the roughage on most

[3] Acknowledgment is made to C. L. Tifft and Carl Tassell, who kept the herd records and rendered other valuable services.

farms, varying amounts of oats, barley, corn, and peas are grown. On some farms, large quantities of purchased concentrates are fed; on others, dependence is placed primarily on the pastures and other green foods, with rather light grain feeding during the winter months when part or all of the herd may be dry. It is evident, however, in either case, that the fact that the larger part of the ration is composed of a good variety of farm-grown foods tends to materially reduce the cost of production, and this should be borne in mind later when the conclusions from the study are being discussed.

Facilities for transportation play an important part in developing a dairy region.[4] At the present time few counties are so well equipped with railroads as is Jefferson County. Radiating from the city of Watertown, nearly at the center, these railroads reach out into almost every part of the county. Milk trains from any part of the county reach New York in twelve hours.

Good dairy farms are valued at from sixty to eighty dollars an acre. The average size of farm for the county is about one hundred and twenty-five acres, but most farms in the dairy region exceed the average. Farm operations in the county are extensive rather than intensive, and to this the milk-producing industry is no exception.

EXPLANATION OF DATA

(From reports of cow-testing associations)

The period covered by this study is substantially the year from April 1, 1913, to March 31, 1914. The association record books used for the various herds under consideration were those supplied by the New York State Department of Agriculture. The summary sheet from each complete herd report was carefully examined and the following data for the year were drawn off: number or name of cow, age, milk yield, percentage of fat, butter-fat, cost of roughage, cost of grain, and amount received for milk. This information gives the yield of milk, butter-fat, total cost of feed, and amount of money received for each cow's product. For the benefit of those unfamiliar with the organization and purpose of a cow-testing association, the following brief outline of one is given, as showing how the production and feed costs per cow were obtained:

Organization and purposes of a cow-testing association [5]

As in any other association, there is usually a formal organization providing for officers and for a set of by-laws for the government of the

[4] Jefferson County: an account of its agriculture and of its farm bureau. By F. E. Robertson. Cornell Univ. Agr. Exp. Sta. Farm bureau circ. No. 4. 1914.
[5] The formation of cow-testing associations. By Henry H. Wing. Cornell Univ. Agr. Exp. Sta. Circ. No. 17. 1913.

association. Each association holds meetings at stated times. Each member joining an association signs a definite agreement as to the number of cows he will enter in the test, the cost per cow, when payment shall be made, and other data, in order that the organization may be put on a sound financial basis. Some cow-testing associations are affiliated with other organizations, in which case formal by-laws may not be necessary. Such associations are usually cooperative.

While organization may be effected in various ways, the important thing is that it should be planned with due regard to local conditions. After proper organization is effected, the affairs of the association are placed in charge of competent officers who engage a properly qualified man to visit the various herds and do the testing. That such associations are useful to a high degree is shown by their increasing numbers in New York and in other States.

For more than twenty years the use of the scales and the Babcock test, and their importance in determining the butter-fat production of the various cows in the herd, has been continuously urged on dairymen and breeders of dairy cattle in this State. With the exception of breeders of pure-bred dairy cattle, milk producers in general have been very slow to systematize their business, even to the extent of keeping individual milk records. To weigh the milk and make the butter-fat tests imposes no qualifications that an ordinary person should be unwilling to acquire. For various reasons the busy dairyman has refused to do these things for himself. Frequently, however, he is willing to join an association, and through cooperation encourage the testing and improvement of all cows in the community. While testing through an association secures for the individual little more than he could as well obtain for himself, yet it may encourage the idea of cooperation, which is so helpful in general live-stock improvement.

Details of organization.— Usually an association is composed of twenty-five or twenty-six dairies so grouped that they are accessible and each may be visited once every month. The owner weighs the milk from each cow, continuously or at stated intervals, during the month. Samples of milk from each cow may be taken by the owner, to be ready when the tester arrives, or by the tester himself on his arrival, depending on the convenience of those concerned. In any event, every farm must be visited in turn each month, and all records of feed and production per cow obtained. The tester makes the butter-fat tests, calculates the production of fat for each cow per month, records the feed consumed and the production, and leaves a report of each visit with the owner on a blank form provided for the purpose.

Much depends on the tester employed. He must take interest in his work and be able to make a reliable Babcock test. All calculations

must be made accurately, rapidly, and neatly. The tester must command the respect of the members of the association he serves, and his usefulness is greatly increased if he can advise the dairymen on feeding and other questions.

Apparatus needed.— A spring balance of sixty pounds capacity, graduated to tenths of a pound, is an essential in every dairy stable. Record sheets for daily weights of milk, and record books for entering all records of each cow, are provided by the association. Where the owners take the samples, as many wide-mouth sample bottles are needed as there are cows in the herd. Each bottle should have a durable label. A convenient sampling dipper must be provided for taking the sample to be tested.

The tester carries with him a Babcock testing machine, usually the twelve-bottle hand-power size. Larger sizes are used where steam is available. The tester has also a full supply of State-inspected glassware, in order to insure accuracy of results. Sulfuric acid, used in making the test, is usually kept on hand at the various farms. The quantity required for one cow for a year is approximately one pint, or two pounds. If the tester does not provide his own conveyance, each member of the association carries him in turn to the next member. His living expenses are borne by those whom he serves.

Purposes of an association.— The primary objects of a cow-testing association may be enumerated as follows :

1. To identify and eliminate the unprofitable cows in every herd, and thus make the business of milk production more profitable.

2. To determine which cows are sufficiently profitable to justify their use in grading up a better herd.

3. To point out the losses from low-producing cows and the necessity for high-yielding animals of good breeding.

4. To encourage the idea of cooperative effort among dairymen.

Obviously there are many other things accomplished, the most important of which is the securing of a mass of useful data covering many points of economic interest. The dairyman who enters his cows for such a test does so for the purpose of accurately informing himself as to the real merit of each cow. While the approximate day when the tester will arrive each month is known in advance, there is no temptation to falsify records or manipulate the cows in any way. Such records are for the owner's information primarily, and, being unofficial, can have but little effect on the selling price of any individual cow that might be offered.

The records

The accuracy of such records of production and food consumption as are obtained is greater than that of records frequently in use. With

each individual cow's record at hand, it has not been necessary to base calculation on an estimate of the quantity of milk used for calves and domestic purposes, and add this to the farm deliveries at the creamery or milk station. The frequent weighings of grain and roughage to each cow are much more nearly accurate than a rough apportionment at irregular intervals of the food supplies on hand to the number of animals being fed. In other words, the production per cow, the feed cost per cow, and the receipts per cow, in the tables that follow, were obtained in such a way as to give them an unusual degree of accuracy.

Further, it should be said that the breeding of each herd is indicated as either pure-bred, grade, mixed, or scrub. Only cows with full yearly records were used. All other data were obtained from using on each farm the survey blanks, which are explained later.

Feed costs in the association

A word regarding feed costs is important, not so much for the purpose of showing how they were obtained as to give the basis for future calculations or comparisons of cost. The roughages used were pasture, mixed hay, corn silage, fodders, and a small quantity of alfalfa hay. Only eight owners reported the feeding of alfalfa hay, and vetch hay was used to a very slight degree.

Pasture costs per cow varied in the different associations from $1 to $1.50 a month, depending somewhat on the value of the land. Mixed hay, which was generally fed, had an average farm value of $12 a ton. Corn silage was calculated at $4 a ton.

Farm-grown grains were charged to the cows at farm value, which varied somewhat with locality and quality. All purchased feeds were charged at actual cost, being hauled on the return trip from the creamery or milk station. The common grains and by-products used were corn, oats, barley, peas, wheat bran, wheat middlings, buckwheat middlings, hominy, brewers' dried grains, gluten feed, oil meal, and cottonseed meal. In 32 per cent of the herds, "ready-mixed" dairy rations were fed as all or part of the concentrate.

As nearly as can be stated, the average cost of purchased concentrates in all herds was $30 a ton. A statement of feed costs for each herd would be more confusing than useful. However, with the valuations already given, and the fact borne in mind that the average net feed cost per cow was 64 per cent of the total net cost (as shown in the tables following), the effect of any change in feed values on cost of production can be readily calculated.

SURVEY OF EACH FARM

In order to determine the items other than cost of feed that enter into cost of production, a careful survey of each farm relative to live-

stock activities was made. The complete survey and summary of a typical herd, No. 1, is given (Tables 1 and 2), in order to show the method of procedure. Since the records of production and feed costs for each cow were available, it seemed desirable and feasible to obtain the other costs, in so far as possible, on the basis of the individual. In order to do this, all charges of a definite or individual nature were made against each cow. The collective, or herd, costs, which could not readily be subdivided, were apportioned equally as shown in the following explanation:

Discussion of various items

Inventory of cows.— By a careful consultation with the owner or the manager of each herd, the value of every cow was determined at the beginning and the close of the year in question. The values assigned represent the owner's estimate, with the exception that in a number of herds, where there were pure-bred cows inventoried at relatively high prices, the value of these cows was reduced to one hundred dollars in order to put them on the same milk-producing basis as grade cows with essentially the same records. In other words, in this study the interest on investment charge in no case exceeds $5 per cow for the year. All interest charges, under this heading or elsewhere in this bulletin, were calculated at 5 per cent.

Value of calf.— When possible the value of each calf was obtained, and the average of all calves for the herd was credited to the cows in determining the fixed cost per cow. There were specific cases when calves were given a high individual value. In this bulletin no credit of more than $10 per calf was allowed, as the larger amounts can hardly be considered a legitimate compensating factor in milk production. Credit for the calf in this connection is but an arbitrary offset for food diverted to purposes of reproduction.

Value of manure.— There was so much variation between the estimates given by the dairymen as to the value of the manure obtained from a dairy cow during the year, that it seemed necessary to assume for each cow a uniform credit of $15 and for a bull $10. These credits are in common use elsewhere and are so used throughout this text.

Bull service.— The feed cost in keeping a bull is largely an estimate. While the records of food for cows are available, few owners have made similar records for the bulls. It so happened that none of the inventory values on bulls were high. The net cost of bull service to the herd was determined by subtracting the credit, if any, for outside service, and the value of manure, from interest on average value plus estimated cost of keep. The gross cost for service to the herd was distributed to the various cows, as shown in fixed costs, Table 2.

TABLE 1. SURVEY BLANK USED ON EACH FARM TO DETERMINE HERD OPERATING COSTS

Farm survey — Milk production

Name, No. 1	Post office	Township
Owner	Miles to market, 2	Age, 37
Size of farm, 156 acres	Share renter, yes	Cash renter
Number of cows, 27	Number of heifers, 4	Number of calves, 4
Number of bulls, 1	Other stock, 0	
Number of horses, 3	Number of colts, 0	C. U., 32

Number of cow	Inventory			Value of calf
	1st	2d	Average	
1	$85.00	$75.00	$80.00	$2.50
2	70.00	60.00	65.00	4.00
3	85.00	75.00	80.00	4.00
4	85.00	75.00	80.00	4.00
5	85.00	75.00	80.00	3.00
6	85.00	70.00	77.50	....
7	80.00	70.00	75.00	5.00
8	60.00	50.00	55.00	2.00
9	70.00	60.00	65.00	5.00
10	50.00	50.00	50.00	2.00
11	80.00	75.00	77.50	2.00
12	80.00	75.00	77.50	2.00
13	70.00	60.00	65.00	3.00
14	85.00	75.00	80.00	5.00
15	50.00	60.00	55.00	2.00
16	40.00	50.00	45.00	2.00
17	40.00	50.00	45.00	2.00
18	70.00	75.00	72.50	2.00
19	70.00	75.00	72.50	2.00
20	70.00	75.00	72.50	2.00
21	70.00	75.00	72.50	2.00
22	70.00	60.00	65.00	3.00
23	50.00	40.00	45.00	2.00
24	70.00	60.00	65.00	2.00

Bull service

Average value of bull, $75.00, at 5 per cent	$ 3.75	....
Depreciation	....	....
Cost of keep	35.00	....
Outside service	....	....
Manure	....	$10.00
Total	$38.75	$10.00
Net cost	28.75	....

TABLE I (*continued*)

Value of manure per cow estimated at $15 per year

Bedding	Kind	Tons	Value per ton	Total
Straw	Oat	5	$6.00	$30.00

Hauling milk

Farmer hauls, part time	Cooperates, no	Hires, 3 months	Driver, man
Time required, 2 hours	Distance, 2 miles	Number of trips a year, 270	Number of horses, 1

Cost of man labor at 15c., 540 hours	$81.00
Cost of horse labor at 12c., 540 hours	64.80
Cost of portion hired hauled	15.00

Amount of milk hauled, 152,718 pounds
Cost per hundredweight, 10½ cents

Labor on milking cows

	Hours	Days	Total hours	Cost
Summer — average per day	6	180	1,080	....
Winter — average per day	6	185	1,110	....
Extra time on cows	....	....	....	....
Making products	....	....	....	....
Child labor	....	....	....	....
Woman labor	1	365	365	....
Horse labor	....	....	....	....
Total			2,555	$383.25

Dairy equipment

	First inventory	Second inventory
Cans	$15.00	$12.00
Pails and strainers	1.25	1.00
Cooler	2.25	2.00
Tester and bottles	....	....
Wagon	15.00	10.00
Scales	2.30	2.00
Separator	....	....
Churn	....	....
Total	$35.80	$27.00
Average	31.40	....
Decreased inventory	$ 8.80	....
New equipment	....	....
Repairs	....	....
Interest average inventory	1.57	....
Total	$10.37	....
Less increased inventory	....	....
Cost	....	....

TABLE 1 (*concluded*)

Buildings

	First inventory	Second inventory
Dairy barn	$2,000.00	$2,000.00
Silos	150.00	200.00
Milk house	20.00	30.00
Ice house	....	....
Total	$2,170.00	$2,230.00
Average	2,200.00	....
Decreased value	....	....
Repairs — total	$150.00	....
Interest average inventory	110.00	....
Insurance	1.50	....
Total	$261.50	....
Less increased inventory	60.00	....
Cost	$201.50	....

Memorandum — Barn repairs

	Amount	Value	Total
Purchased lumber	....	....	$ 25.00
Shingles, roofing	....	....	100.00
Hardware	....	....	....
Paint, glass	....	....	....
Cement, sand, lime	....	....	....
Materials from farm	....	....	....
Labor — skilled	....	....	25.00
Labor — farm	....	....	....
Labor — horse	....	....	....
Labor — board of	....	....	....
Total	....	....	$150.00

Miscellaneous costs

	Amount
Insurance on stock	....
Medicines	$ 8.00
Veterinary fees	....
Fly protector	1.00
Skimmed milk	....
Stock foods	7.80
Ice	....
Grinding	2.00
Overhead charges — cattle and testing	35.60
Total	$54.40

Bedding.— In many herds bedding was not used. If shavings or the like were bought, the amount and cost were recorded; if straws and other farm refuse were used, their value was estimated. The total cost for bedding for the herd was used as a part of the fixed costs as shown in Table 2.

Hauling milk.— The cost of hauling milk per hundred pounds was determined for each herd by obtaining the number of men and horse hours required to move the year's product of milk to factory or station. A uniform charge per hour of 15 cents for a man and 12 cents for a horse was made in all cases. All milk hauled from the farm during the year, including that of both full-term and short-term cows, was used in determining the cost per hundred pounds. In this way it was possible to charge each cow accurately with the delivery of her product.

Labor on cows.— The approximate hours required on the different farms for milking and caring for the cows was determined by consultation, and the cost was figured at 15 cents an hour. It should be noted that the amount of labor as estimated by the dairymen included the care of the whole herd. In certain herds, but not in all, there were cows that freshened or went dry at such times as to give them incomplete records for the year. As noted elsewhere, all such cows were discarded. The number of cows eliminated in this manner was not sufficient, however, to materially affect the labor charge. In each case the labor costs for the whole herd were distributed to the different cows under fixed costs as shown in Table 2.

Dairy equipment.— This is usually a small charge, from the fact that, while dairy equipment has rather a short period of usefulness on most farms, the amount of capital invested in this form at any one time is relatively small. Such items as pails, cans, coolers, wagons, and the like, belong in this group. The cost for dairy equipment on each farm was determined from the difference in inventory values, the costs for repairs, and the interest on average investment, the total cost becoming a part of the fixed charge.

Buildings.— The inventory value was obtained, at the beginning and the end of the year, of all barns, silos, and other buildings used to shelter the cattle or provide storage for feed or product. When the barn was so arranged that the cattle and other stock not concerned in this project were housed together, a fair proportion of the total value of the barn was assigned to the cattle. The charge for buildings against all cattle was then obtained by proceeding as outlined in the survey of herd 1, Table 1. In order to apportion the costs for shelter and storage equally in every herd, however, all cattle kept during the year, including bulls and calves, were reduced to cattle units. A heifer or a calf was con-

sidered one-half unit. If there were 32 cattle units and 24 milch cows, and the total cost for buildings during the year was $201.50, the charge against the milch cows would be three-fourths of $201.50, or $151.13. This gives the total charge for housing the milch cows, and becomes one item in the list of fixed costs.

TABLE 2. BLANK FOR SUMMARIZING HERD DATA

Herd summary

Farm survey—Milk production

Herd costs	Total	Per cow	Average
Bull service	$ 28.75	Hauling milk per 100 pounds	$ .105
Bedding	30.00	Value of calf	2.25
Labor	383.25	Value of manure	15.00
Dairy equipment	10.37		
Buildings ‡‡	151.13	Mixed grades	
Miscellaneous	54.40		
Average fixed cost per cow	$27.41		

Cow		Total milk (pounds)	Total butter-fat (pounds)	Total cost of feed	Fixed costs	Interest on invest-ment in cow plus hauling costs	Value of manure and calf	Net cost	Rec'd for milk	Cost of 1 pound butter-fat	Cost of 100 pounds milk
Num-ber	Age (years)										
1	9	7,993	281	$52.55	$27.41	$12.39	$17.25	$75.10	$126.13	$.267	$ .94
2	10	5,213	190	51.84	"	8.72	"	70.72	87.55	.372	1.36
3	7	6,253	276	53.79	"	9.47	"	73.42	102.20	.266	1.17
4	7	7,055	207	45.82	"	11.40	"	67.38	102.94	.325	.95
5	6	6,724	241	53.87	"	11.06	"	75.09	108.04	.311	1.12
6	7	6,094	246	55.12	"	10.24	"	75.52	108.53	.307	1.24
7	11	5,747	181	39.49	"	9.88	"	59.53	89.75	.329	1.04
8	11	6,698	194	56.09	"	9.78	"	76.03	103.41	.392	1.13
9	9	7,044	199	56.57	"	10.64	"	77.37	106.12	.389	1.10
10	10	5,593	187	52.38	"	8.37	"	70.91	88.64	.379	1.27
11	16	7,041	191	54.80	"	11.29	"	76.25	103.40	.399	1.08
12	6	6,453	221	49.73	"	10.62	"	70.51	102.18	.319	1.09
13	5	5,005	176	45.17	"	8.50	"	63.83	88.86	.363	1.27
14	3	5,444	195	54.32	"	9.71	"	74.19	91.81	.380	1.36
15	3	3,905	146	47.97	"	6.85	"	64.98	66.64	.445	1.66
16	3	3,260	136	45.59	"	5.67	"	61.42	54.17	.452	1.88
17	3	4,310	159	51.21	"	6.77	"	68.14	73.14	.428	1.58
18	4	3,397	137	50.60	"	7.21	"	67.97	55.78	.496	2.00
19	5	4,949	182	53.85	"	8.79	"	72.80	78.54	.400	1.47
20	5	5,092	220	53.70	"	8.94	"	72.80	87.77	.331	1.43
21	5	5,989	184	65.76	"	9.93	"	85.85	86.20	.466	1.43
22	7	5,920	207	51.61	"	9.46	"	71.23	92.34	.344	1.20
23	7	4,620	162	45.68	"	7.10	"	62.94	81.78	.388	1.36
24	8	5,895	254	48.13	"	9.43	"	67.72	105.07	.267	1.15
Total		135,694	4,772	$1,235.64	......	$222.22	....	$1,701.70	$2,190.99	......	....
Average		5,654	199	51.48	$27.41	9.26	$17.25	70.90	91.29	$.356	$1.25

Miscellaneous costs.— There are a variety of items, including emergencies and the costs of herd testing, that can best be assembled in a group by themselves. These likewise are a part of the fixed costs as shown in Table 2.

Fixed costs.— In tabulating the cost items involved in the conduct cf any business, there are likely to be charges of a definite nature which cannot be easily apportioned to the various factors in the enterprise. So it is with milk production. Consequently, in every herd summary, the total net cost for bull service, bedding, labor, dairy equipment, buildings, and miscellaneous charges, was divided equally among the cows,

FIG. 60.— *Dairy barn, silo, and cattle on farm No. 1; herd 1, referred to in Tables 1 and 2*

and the result was made a fixed charge in the statement for each cow in that herd. This constitutes what is called the fixed, or overhead, charge, the individual items of which have been explained under the preceding headings.

Herd summary

For convenience in studying the individual receipts and expenditures for each cow, the figures were tabulated as shown on the herd summary blanks, Table 2. The milk, butter-fat, and feed cost items were taken from the records of the testing associations. In order to determine the fixed, or definite, costs per cow, the sum of the various charges already referred to was divided by the number of cows. For convenience in

tabulating, the interest on the average investment in cow during the year, and the cost of delivering her product at the rate indicated per hundred,

TABLE 3. AVERAGE YIELD AND COSTS FOR 834 COWS IN 53 HERDS, JEFFERSON COUNTY

Herd number	Total average milk (pounds)	Total average butter-fat (pounds)	Total cost of feed	Fixed costs	Interest on invest-ment in cow plus hauling costs	Value of manure and calf	Net cost	Rec'd for milk	Cost of 1 pound butter-fat	Cost of 100 pounds milk
1	5,654	199	$51.48	$27.41	$ 9.26	$17.25	$ 70.90	$ 91.29	$.356	$1.25
2	6,627	229	44.71	53.86	16.83	18.85	96.55	110.54	.422	1.46
3	4,524	156	33.33	20.07	4.21	17.50	40.11	74.61	.257	.89
4	6,755	253	68.01	32.40	10.49	17.10	93.80	114.94	.371	1.39
5	7,764	291	58.05	43.35	7.99	17.75	91.64	128.82	.315	1.18
6	5,689	204	39.01	38.41	11.66	17.50	71.58	92.82	.351	1.26
7	6,037	207	35.69	34.78	16.57	17.50	69.54	97.18	.336	1.15
8	6,301	222	48.67	57.59	6.33	17.50	95.09	79.95	.428	1.51
9	5,206	186	34.03	42.10	8.55	17.50	67.18	70.99	.361	1.29
10	6,572	231	42.21	36.44	22.15	17.50	83.30	102.30	.361	1.27
11	5,881	217	32.61	27.04	7.22	17.50	49.37	76.20	.228	.84
12	7,862	260	55.48	36.49	9.35	17.36	83.96	127.06	.323	1.07
13	6,601	234	44.42	32.60	10.25	18.61	68.66	106.58	.293	1.04
14	5,529	207	45.60	31.33	15.01	17.00	74.94	92.00	.362	1.36
15	8,840	317	62.89	34.19	13.09	18.92	91.25	140.48	.288	1.03
16	6,582	223	56.80	47.84	11.83	18.57	97.90	99.88	.439	1.49
17	11,476	423	88.92	42.20	8.02	19.30	119.84	169.92	.283	1.04
18	7,064	266	57.43	34.37	8.07	16.75	83.12	96.45	.312	1.18
19	6,425	224	58.93	34.23	9.37	17.00	85.53	92.83	.382	1.33
20	7,896	281	56.85	78.12	11.40	25.00	121.37	125.66	.432	1.54
21	7,156	265	60.04	52.77	18.13	17.00	113.94	105.65	.430	1.59
22	5,891	199	46.01	38.31	15.84	17.00	83.16	90.99	.418	1.41
23	9,686	347	66.73	36.15	17.70	17.85	102.73	141.51	.296	1.06
24	5,599	202	54.77	33.73	26.04	16.75	97.79	85.52	.484	1.75
25	8,958	335	61.94	43.71	13.01	17.61	101.05	120.81	.302	1.13
26	5,950	214	59.94	36.75	13.37	17.10	92.96	92.60	.434	1.56
27	6,705	230	52.11	33.81	7.61	16.90	76.63	100.88	.333	1.14
28	5,643	198	47.85	41.48	12.49	18.16	83.66	84.64	.423	1.48
29	9,863	337	76.85	64.60	25.15	25.00	141.60	157.13	.420	1.44
30	5,666	234	48.63	32.94	6.09	17.26	70.40	83.09	.301	1.24
31	6,084	203	51.69	41.44	19.34	17.16	95.31	90.50	.470	1.57
32	7,943	290	77.74	50.04	6.19	21.96	112.01	119.64	.386	1.41
33	6,542	238	64.14	61.80	14.41	25.00	115.35	97.38	.485	1.76
34	5,521	197	40.08	26.16	7.19	16.50	56.93	79.01	.289	1.03
35	8,291	322	80.64	37.48	9.63	16.82	110.93	148.22	.345	1.34
36	6,320	224	42.61	40.36	9.59	25.00	67.56	79.32	.302	1.07
37	6,331	215	52.91	30.47	11.52	17.00	77.90	100.35	.362	1.23
38	5,064	214	38.25	24.77	10.62	16.50	57.14	73.85	.267	1.13
39	7,445	271	49.37	37.33	16.57	17.00	86.27	102.47	.318	1.16
40	8,357	331	67.38	48.91	13.81	17.14	112.96	204.54	.341	1.35
41	6,132	294	49.56	12.66	6.41	17.81	50.82	95.79	.173	.83
42	7,758	251	66.56	42.93	10.35	18.00	101.84	121.08	.406	1.31
43	5,775	216	44.44	23.50	10.00	16.75	61.19	79.39	.283	1.06
44	5,554	181	36.98	28.85	21.95	17.00	70.78	75.19	.391	1.27
45	6,681	231	50.72	18.36	10.58	20.32	59.34	96.90	.257	.89
46	7,213	243	62.69	44.01	19.38	17.75	108.33	112.11	.446	1.50
47	7,494	200	43.30	29.86	6.93	19.17	60.92	104.29	.234	.81
48	7,989	277	67.43	42.05	11.38	25.00	95.86	116.13	.346	1.20
49	5,424	224	48.47	29.51	5.42	16.67	66.73	85.30	.298	1.23
50	7,785	286	57.47	36.39	7.17	17.00	84.03	110.93	.294	1.08
51	6,127	221	38.43	28.38	9.40	16.50	59.71	80.86	.270	.97
52	4,965	177	30.02	23.15	9.48	16.75	45.90	67.31	.259	.92
53	6,320	228	53.06	54.70	13.19	16.50	104.45	91.03	.458	1.65
Average of total production and cost	6,621	241	$51.57	$35.65	$11.25	$18.23	$80.24	$100.63	$.333	$1.21+

are combined into one item. The net cost per cow is obtained by deducting the average value of calf and manure in any particular herd, from the sum of feed cost, fixed cost, hauling cost, and interest on invest-

ment in cow. The cost of one pound of butter-fat or one hundred pounds of milk, therefore, is determined from the yield of each cow and the net cost of keeping her for a year.

The significant thing in this study of milk production is the opportunity offered, through test association records of the herds involved, to determine the costs that each cow bears and consequently the relation of her scale of production to profit. Few reports thus far made have carried the comparison of all costs to the individual. The methods of calculation and tabulation used here seemed best suited to this particular problem, although they might not be so applicable under other conditions.

HERD AVERAGES

The average yields and costs in each herd and in all herds are given for reference in Table 3. The general facts of interest on production, cost, and profit, are given in condensed form in Table 4. It is shown that the cost per cow for producing 6621 pounds of milk was $80.24, or $1.21 per hundred pounds. The average value of the product was $100.63 per cow. Deducting the cost of producing the milk from the amount received, an average profit of $20.39 per cow, or 31 cents per hundred pounds of milk, was made. On the same basis, a pound of butter-fat cost 33.3 cents. The average selling price of milk in all herds was $1.52 per hundred pounds, and the average profit was 31 cents per hundred pounds.

TABLE 4. AVERAGE PRODUCTION, COST OF PRODUCTION, AND PROFIT, FOR 834 COWS

Item	Production per cow (pounds)	Cost		
		Per cow	Per 100 pounds milk	Per 1 pound butter-fat
Milk yield	6,621			
Butter-fat	241			
Cost of feed		$51.57	$ .78	$.214
Fixed costs		35.65	.54	.148
Interest on investment in cow plus hauling costs per cow		11.25	.17	.047
Total gross cost of production		$98.47	$1.49	$.409
Credit by calf and manure		18.23	.28	.076
Net cost of production		$ 80.24	$1.21	$.333
Value of production		100.63	1.52	....
Average profit		$20.39	$ .31	....

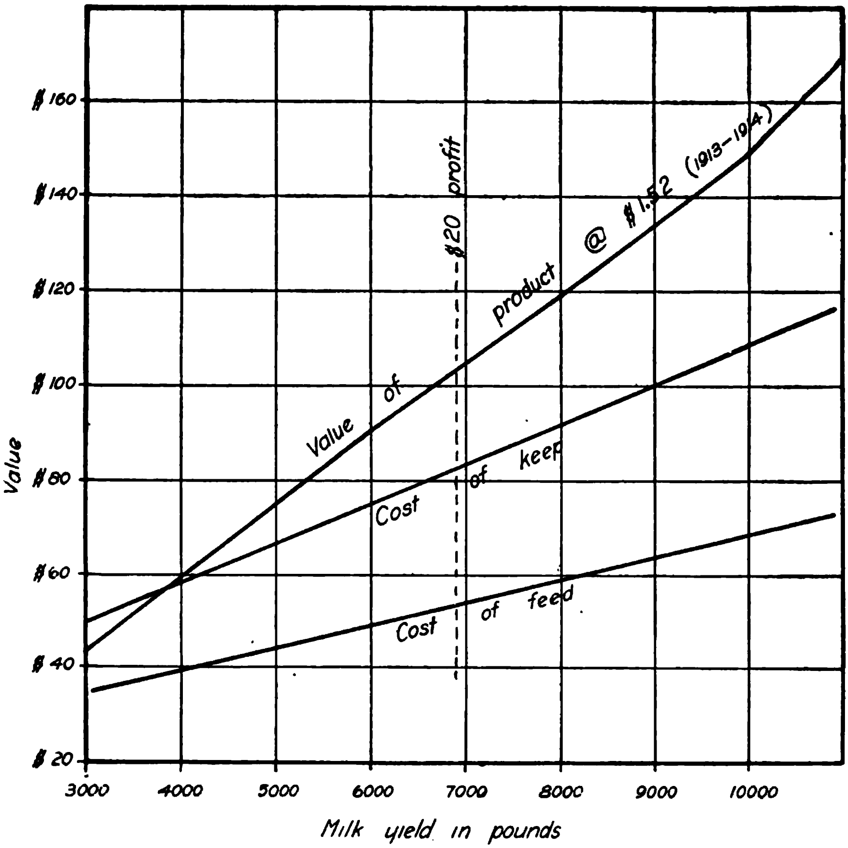

FIG. 61.— *Relation of cost of feed, cost of keep, and value of product, to yield of milk*

YIELD, COST, AND PROFIT

Facts of considerable interest are emphasized in Table 5, in which the cows are grouped according to milk yield in order to show the relative profit of individuals having different abilities for production. In this respect the table is self-explanatory except with regard to the first group. Of the 159 cows producing 5000 pounds of milk or less, only 13 gave less than 3000 pounds a year. Four of these were more than four years old.

The average cost of feed per cow was $51.57, or 64 per cent of the net cost. The statement has been made that "the products sold from the average cow little more than pay for the feed."[6] The average production of the first group coincides closely with the average yield of a cow in New York State. In this group there was a profit of $6.04 per cow.

[6] Some important factors for success in general farming and in dairy farming. By G. F. Warren. Cornell Univ. Agr. Exp. Sta. Bul. 349:684. 1914

This low production was due to some extent to the large proportion of cows in the group coming from herds 3 and 11, in which feed, labor, and investment costs were unusually low (Table 8, page 642). In view of these facts, Table 5 indicates not only the financial peril inherent in the ownership of average cows, but also the greater relative efficiency of cows as their production increases.

TABLE 5. RELATION OF YIELD TO COST AND PROFIT FOR 834 COWS. COMPARISON OF GROUPS OF DIFFERENT PRODUCTIVE ABILITY

Group	Number of cows in group	Average production	Net cost of production	Value of product	Profit per cow	Net cost per 100 pounds of milk	Profit per 100 pounds of milk
5,000 pounds or less	159	4,161	$ 57.20	$ 63.24	$ 6.04	$1.37	$.15
5,001-7,000 pounds	360	5,993	74.40	91.09	16.69	1.24	.28
7,001-9,000 pounds	214	7,843	92.00	119.21	27.21	1.17	.35
9,001-11,000 pounds	84	9,763	109.00	148.39	39.39	1.12	.40
Over 11,000 pounds	17	12,377	112.60	188.13	75.53	.91	.61
Total..........	834	......	....	....	......	......	....
Average........	....	6,621	$ 80.24	$100.63	$20.39	$1.21	$.31

MISCELLANEOUS HERD COSTS

In determining the herd costs on the different farms, certain data became available which are given for reference in Table 6. While the results from one farm are in no way conclusive, the variety and distribution of the farms enumerated is of such a nature as to give considerable weight to the averages. The total amount of milk delivered from the fifty-three farms was 6,582,183 pounds, and this amount is used later as the basis for computing the cost of hauling. From the total man and horse labor, it is possible to find the amount of each required per cow or per farm.

Hauling costs

The cost of hauling on different farms affords some striking contrasts, due to the amount hauled and the length of haul. A tabulation of the costs for hauling is summarized in Table 7. The average length of haul was 2.14 miles, at a cost of 5.5 cents per hundred pounds per mile. The average cost on all farms of man and horse labor to deliver one hundred pounds of milk was 11.7 cents. Of this amount 4.8 cents was expended for man labor and 6.9 cents for horse labor. The average hauling cost per farm per year was $145.16.

The distance to market and the condition of the roads are important considerations to the dairyman who must make daily deliveries. A long haul is obviously expensive, unless the amount of milk delivered is relatively large. Long hauls with small amounts are the most expensive, and large amounts with short hauls are the least expensive, per hundred pounds of milk.

TABLE 6.—MISCELLANEOUS HERD COSTS

Herd number	Number of cows	Milk hauled (pounds)	Number of miles hauled	Man labor hauling	Horse labor hauling	Cost for hauling 100 pounds	Man labor care	Value of bull	Net cost of bull service
1	24	152,718	2.00	$ 81 00	$ 64.80	$.105	$383.25	$ 75.00	$28.75
2	7	61,760	4.00	49.50	79.20	.208	278.55	100.00	20.00
3	49	338,984	.25	54.75	87.60	.042	710.25	100.00	40.00
4	15	114,288	4.00	49.50	79.20	.113	329.25	100.00	20.00
5	23	186,521	2.50	40.95	65.52	.057	575.25	40.00	30.00
6	19	138,532	2.50	81.90	131.04	.154	438.75	50.00	40.50
7	22	133,826	4.00	117.00	187.20	.227	396.00	50.00	22.50
8	11	78,146	1.00	18.75	15.00	.043	383.25	50.00	17.50
9	12	62,478	2.00	36.15	28.92	.104	364.95	50.00	17.75
10	15	124,793	3.00	136.50	218.40	.284	382.50	75.00	13.75
11	12	72,683	1.50	27.30	21.84	.068	109.35	75.00	28.75
12	11	96,886	1.50	27.15	43.44	.073	243.80	35.00	48.75
13	13	116,579	5.00	42.75	68.40	.095	297.75	50.00	32.50
14	19	138,137	2.00	109.50	175.20	.206	473.25	25.00	21.25
15	14	134,970	3.00	54.60	87.36	.105	329.10	100.00	30.00
16	7	86,420	1.00	54.75	43.80	.114	216.00	100.00	20.00
17	1c	147,434	1.50	21.30	25.56	.032	280.50	45.00	32.25
18	10	86,335	.25	21.75	34.80	.066	216.30	30.00	31.50
19	15	114,958	1.00	30.30	48.48	.069	370.80	200.00	40.00
20	13	166,011	1.00	54.75	87.60	.086	756.75	1,200.00	50.00
21	9	106,875	4.00	83.25	133.20	.203	328.50	....	13.00
22	14	82,485	3.00	68.25	109.20	.215	411.30	35.00	26.75
23	22	244,820	4.00	135.00	216.00	.143	465.75	75.00	50.75
24	18	102,550	3.00	164.25	262.80	.416	451.35	100.00	35.00
25	23	240,673	3.00	90.00	144.00	.097	591.00	40.00	32.00
26	17	119,360	5.00	82.35	131.76	.179	355.65	75.00	33.75
27	24	208,447	2.00	56.25	90.00	.07c	544.50	100.00	30.00
28	12	90,091	1.00	54.75	87.60	.158	278.00	100.00	52.00
29	12	168,495	4.00	136.87	219.00	.211	328.5c	110.00	45.50
30	24	153,867	.25	27.30	43.80	.046	465.60	75.00	28.75
31	17	125,858	3.00	135.00	216.00	.279	462.75	75.00	38.75
32	28	230,557	.25	27.45	21.96	.021	994.65	250.00	77.50
33	11	100,371	3.00	51.00	93.60	.144	361.35	250.00	87.50
34	14	77,278	2.00	22.80	36.48	.077	204.90	35.00	21.75
35	11	123,458	1.00	54.75	43.80	.080	246.30	100.00	47.00
36	10	77,394	.25	31.50	25.20	.073	291.00	100.00	23.36
37	8	51,496	1.25	27.30	43.80	.138	136.95	75.00	27.75
38	9	45,577	3.00	....	....	.156	133.65	....	9.00
39	8	59,562	2.00	57.30	45.82	.173	232.50	....	6.75
40	6	75,171	1.00	54.75	43.80	.131	264.30	....	6.00
41	27	164,070	4.00	54.00	43.20	.059	259.00	75.00	23.75
42	11	113,178	1.50	36.55	56.88	.083	293.40	85.00	47.25
43	12	69,310	2.50	40.60	43.20	.121	130.20	50.00	32.50
44	18	107,981	3.50	144.00	230.40	.347	397.95	70.00	23.50
45	14	113,538	.50	45.00	72.00	.103	125.10	100.00	35.00
46	5	51,974	1.50	42.75	68.40	.214	165.00	....	8.00
47	17	168,404	1.00	23.75	27.00	.030	287.55	200.00	54.00
48	13	122,293	.50	54.75	43.80	.081	355.50	....	13.00
49	20	125,771	1.50	40.95	32.76	.059	382.50	80.00	34.00
50	24	196,995	1.50	49.50	59.40	.055	546.75	75.00	33.75
51	17	104,162	2.50	42.00	67.20	.105	259.87	50.00	27.50
52	24	119,174	3.00	62.10	99.36	.135	417.37	75.00	16.75
53	14	88,489	1.00	54.75	87.60	.161	576.00	75.00	31.75
Total	834	6,582,183	113.50	$3,160.87	$4,532.38	....	$19,280.29	5,080.00	$1,659.36
Average	......	....	2.14	....	....	$.117	....	$108.09	31.31

FIG. 62.— *Delivering milk at a cheese factory in Jefferson County where seventy thousand pounds of milk are received daily*

TABLE 7. HAULING COSTS PER FARM. 6,582,183 POUNDS OF MILK ON 53 FARMS

	Number of hours yearly	Cost	Per 100 pounds milk
Man labor	398	$ 59.64	$.048
Horse labor	713	85.52	.069
Total	1,111	$145.16	$.117

Average length of haul, 2.14 miles
Rate per mile, $.055 per 100 pounds

Cost of labor in caring for herd

A disadvantage frequently charged against dairying is the confinement and long hours of labor necessary in the work. The records available show that on the farms studied, where the average number of cows per farm was 15.7, it took 25.4 hours of man labor and 45.4 hours of horse labor to deliver the product of one cow for a year. In the care of cows about the farm and stable, each cow required 154.5 hours a year. This is equivalent to 25.4 minutes per cow per day, which checks closely with common observation and practice. The average labor cost for care was $23.12 per cow. Horse labor on the farm as related to the herd was covered in the charge for farm-grown feeds.

OBSERVATIONS ON INDIVIDUAL HERDS AND COWS

While averages are instructive and in many cases conclusive, much can be gained from this study by considering in detail the distribution of

TABLE 8.—COMPARISON OF YIELDS AND COSTS FOR DIFFERENT HERDS

Herd number	Total average milk (pounds)	Total average butter-fat (pounds)	Total cost of feed	Fixed costs	Interest on invest-ment in cow plus hauling costs	Value of manure and calf	Net cost	Received for milk	Cost of 1 pound butter-fat	Cost of 100 pounds milk
				Large yields at low cost						
17.....	11,476	423	$88.92	$42.20	$8.02	$19.30	$119.84	$169.92	$.283	$1.04
23.....	9,686	347	66.73	36.15	17.70	17.85	102.73	141.51	.296	1.06
15.....	8,840	317	62.89	34.19	13.09	18.92	91.25	140.48	.288	1.03
				Feed costs high, labor and investment costs normal						
				Medium yields at fair cost						
5.....	7,764	291	$58.05	$43.35	$7.99	$17.75	$91.64	$128.82	$.315	$1.18
18.....	7,064	266	57.43	34.37	8.07	16.75	83.12	96.45	.312	1.18
39.....	7,445	271	49.37	37.33	16.57	17.00	86.27	102.47	.318	1.16
				Most costs near the average						
				Low yields at low cost						
3.....	4,524	156	$33.33	$20.07	$4.21	$17.50	$40.11	$74.61	$.257	$.89
11.....	5,881	217	32.61	27.04	7.22	17.50	49.37	76.20	.228	.84
				Feed, labor, and investment costs much below the average						
				Large yields at high cost						
29.....	9,863	337	$76.85	$64.60	$25.15	$25.00	$141.60	$157.13	$.420	$1.44
32.....	7,943	290	77.74	50.04	6.19	21.96	112.01	119.67	.386	1.41
40.....	8,357	331	67.38	48.91	13.81	17.14	112.96	204.54	.341	1.35
				Feed, labor, and investment costs much above the average						

TABLE 9.—HERDS PRODUCING MILK AT LESS THAN 90 CENTS PER 100 POUNDS

Herd number	Total average milk (pounds)	Total average butter-fat (pounds)	Total cost of feed	Net cost	Received for milk	Cost of 1 pound butter-fat	Cost of 100 pounds milk	Breed*
3............	4,524	156	$33.33	$40.11	$74.61	$.257	$.89	Scrubs
11............	5,881	217	32.61	49.37	76.20	.228	.84	Grade Ayrshires and Holsteins
41............	6,132	294	49.56	50.82	95.79	.173	.83	Grade and registered Jerseys
45............	6,681	231	50.72	59.34	96.90	.257	.89	Grade and registered Holsteins
47............	7,494	260	43.30	60.92	104.29	.234	.81	Registered and grade Holsteins

* See discussion of herds 3 and 41, pages 644 and 648, respectively.

costs in the different herds, and their relation to yield and profit. The same may be said regarding the records of individual cows. In Table 8 eleven herds are roughly grouped according to yield. Using the average

of the fifty-three herds as a basis, the nature of the costs in each group is indicated. In Table 9 five herds are listed, comprising 119 cows, in which the average cost of producing milk was less than 90 cents per hundred pounds. Economical feeding and low fixed costs made this possible. In Table 10 the records of five cows are compared in such a way as to show marked differences in yield and relative individual efficiency in producing milk and butter-fat.

TABLE 10.— YIELDS AND COSTS FOR THE BEST AND THE POOREST COWS

Item	Comparison based on					
	Cost of milk		Cost of butter-fat		Yield of milk	
Number of herd	47	53	41	53	17	3
Number of cow	9	15	1	15	8	48
Total milk (pounds)	10,251	3,432	11,875	3,432	15,391	1,793
Total butter-fat (pounds)	331	128	457	128	541	90
Total cost of feed	$ 46.23	$35.93	$ 63.02	$35.93	$104.61	$16.80
Net cost of keep	65.11	82.12	69.87	82.12	137.28	21.47
Received for milk	141.31	43.44	168.12	43.44	228.93	34.16
Cost of 1 pound butter-fat	.196	.641	.152	.641	.253	.238
Cost of 100 pounds milk	.54	2.39	.58	2.39	.89	1.19
Profit or loss	76.20	—38.68	98.25	—38.68	91.65	12.69
Breed	Grade Holsteins	Grade Holsteins	Registered Jerseys	Grade Holsteins	Grade Holsteins	Scrubs

Note the contrast between cows 9 and 15, for which the difference in the cost of 100 pounds of milk was $1.85; between cows 1 and 15, for which the difference in the cost of one pound of butter-fat was 48.9 cents; between cows 8 and 48, for which the difference in yield was 13,598 pounds.

PROFIT OR LOSS

Seven of the fifty-three herds were kept at a loss. The total net cost for the 97 cows in these seven herds was $10,164.04. The actual receipts for their product amounted to $8828.33, entailing a loss of $1335.71. In nearly every case these herds were below the average for all herds on milk yield, while their average fixed cost was 36 per cent above the average for all herds. Their failure to pay expenses was probably due in some cases to poor management.

While a consideration of the average of all cows included in this study shows a profit, it should not be assumed that all were profitable. As a matter of fact, 161 cows, or 19 per cent of the 834, failed to balance their account, causing a loss to their owners of $1799.87, or $11.18 per cow, on the basis of net cost and actual receipts for the cows concerned. The average milk yield of these cows was 5334 pounds and their butter-fat production was 195 pounds. Both the milk yield and the butter-fat production were 19 per cent below the average, while all costs slightly exceeded the average. One hundred pounds of milk cost $1.68 and one pound of butter-fat cost 45.8 cents.

In the case of 143 of the 161 unprofitable cows, the age of the cow was known. Of these 143 cows, 28.6 per cent were two years old, 19.7 per cent were three years old, and 51.7 per cent were four years old or older. The average milk yields for the various groups were 5194, 4895, and 5568 pounds, respectively. Thus it is seen that in the unprofitable group older cows predominated, with a production not much greater than that of the two-years-old cows. Obviously the young cows cannot be considered as appreciably affecting the unprofitable group.

HERD MANAGEMENT

On the average there is a slight profit in most herds. Some rather low-yielding cows have made a better showing than others with a much better production. It should be borne in mind that poor management and a poor feed supply may easily offset a cow's natural inclination to make a good record. There are good cows and poor cows in most herds. Some managers are skillful in adjusting the costs so that low-producing cows may show a profit; others, with cows of good type and performance, may feed sparingly but allow other expenses to absorb the profits. Good cows with liberal feeding will usually show a profit unless they are charged too much for needless labor, care, and housing.

The equipment and management of each farm is reflected in the herd performance. Much interest and real profit could be derived if every herd record could be studied in detail. Of course this is impossible, but four herds have been selected as types, a brief discussion of the management and production of which may partially answer the question as to whether or not milk can be produced at a profit under conditions in Jefferson County, and may incidentally show why some conditions are desirable and others are undesirable.

Herd 3

The largest herd studied, No. 3, comprised 49 inferior cows kept under very insanitary and uncomfortable conditions. A hard-worked tenant family struggled to care for the stock and the farm under circumstances that were trying. Lack of equipment and of the common appliances for convenience in milk production, while great, were not sufficient to bestir a comfortable landlord to the mutual advantage of a new order of things.

The farm had neither silage nor succulent feed of any kind for winter use. Little effort was made to balance the ration. The roughage was common mixed hay, largely timothy. The grain was one-half "ready-mixed," supplemented in an aimless way with oats, gluten feed, distillers' grains, and middlings.

Because costs were low, this inferior and badly managed herd made a fair showing. The average net cost of 100 pounds of milk was 89 cents. The cheese factory being at no great distance from the farm, hauling charges were very low. A cheap barn, crowded to its full capacity, gave low shelter cost, and little or no bedding was used. Labor costs (probably underestimated) would naturally be low for reasons already mentioned. The dairy equipment was of little value. While the herd may have paid a profit, an analysis of the conditions prevailing gives the results little except a negative value. Had the product been sold on its merits, this herd would have been in the unprofitable group, where it belongs. Fortunately, most milk is now produced under good conditions. It is

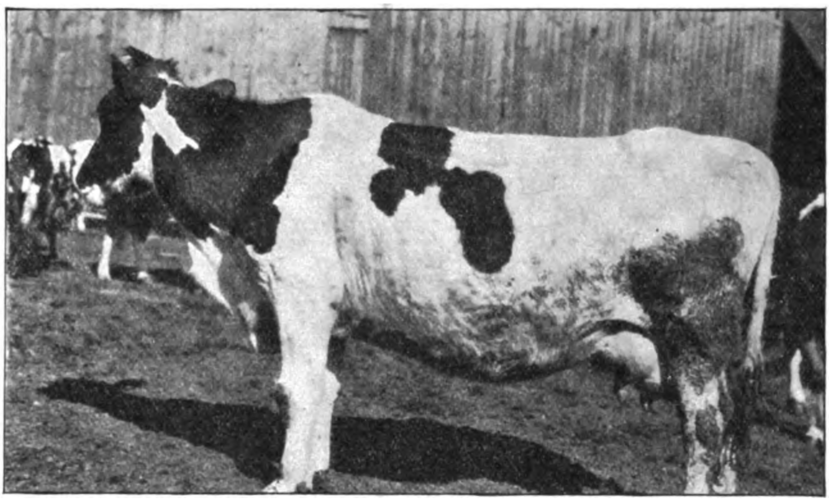

FIG. 63.— *Cow 31, herd 3. The yearly record of this cow was 4833 pounds of milk and 197 pounds of butter-fat. She was considerably above the average of the herd in type and performance*

a regrettable fact, however, that progressive dairymen are obliged to put their honest efforts and wholesome product in competition with such low standards.

Herd 5

The returns from herd 5 are not cited to bring out anything exceptional. The farm is a tenant farm, with only average equipment and facilities, which receives the general supervision of a business man, the owner. The herd is made up of 23 grade Holsteins but little better than the average of all herds here considered, as is borne out by the fact that their average milk yield was but 17 per cent above the average and the cost of producing one hundred pounds of milk was 2.5 per cent below the average. The

income is from surplus grade stock, milk, and hay, the milk receipts constituting the major portion.

A statement of the owner's one-half share of net receipts for the past eleven years is given in Table 11. This shows a return of 5.7 per cent on the approximate investment of $12,200. No charge is made for supervision. While the receipts show a tendency to increase in recent years, this farm, which is evidently above the average, is not an attractive investment. With better cows and more energetic management, a small profit might be made.

TABLE 11.— OWNER'S SHARE OF RECEIPTS FROM HERD 5 FOR ELEVEN YEARS
(Tenant farm)

Year	Owner's share
1903	$581.00
1904	703.00
1905	571.00
1906	558.00
1907	952.00
1908	—247.00
1909	684.00
1910	802.00
1911	1,238.00
1912	740.00
1913	1,054.00
Average	$694.18
Inventory	
Live stock	$2,000.00
Farm and improvements	10,000.00
Miscellaneous	200.00
	$12,200.00
Average shows 5.7 per cent profit on $12,200.	

Herd 17

In the records for herd 17 (Table 12) there is food for reflection. Seven of the 10 cows produced more than 10,700 pounds of milk each. The average for the herd was 11,476 pounds of milk and 423 pounds of butter-fat. This group of 10 cows produced milk at a cost of 14 per cent less, and butter-fat at a cost of 15 per cent less, than that of the average of all herds. Three members of the herd produced jointly 1532 pounds of butter-fat during the year. The average of the five best yearly records, exclusive of association dates, is 14,019 pounds of milk. While the average production of this herd is 73.3 per cent above the average in this study, the net cost of producing is increased 49.3 per cent. The increased

cost of production is offset, however, by a profit 145.6 per cent greater than the average. It is obvious, therefore, that it pays to feed good cows.

TABLE 12.— RECORDS FOR HERD 17

(Farm worked and managed by owner)

Number of cow	Total milk (pounds)	Total butter-fat (pounds)	Total cost of feed	Net cost	Rec'd for milk	Best yearly milk records
1	13,922	493	$ 96.58	$128.79	$207.38	14,536.4
2	12,713	411	90.51	122.35	185.68	15,156.6
3	8,940	321	84.04	113.31	138.34	....
4	9,371	373	85.34	114.44	142.71	....
5	12,832	498	89.80	120.42	186.79	....
6	10,883	421	84.06	115.33	159.30	11,715.1
7	10,748	408	87.85	118.08	159.22	....
8	15,391	541	104.61	137.28	228.93	....
9	10,770	410	88.29	119.52	158.48	17,076.2
10	9,193	349	78.14	108.89	132.32	11,610.4
Average	11,476	423	$ 88.92	$119.84	$169.92	14,018.9

Fixed costs	$42.20
Interest on investment in cow plus hauling costs	8.02
Value of manure and calf	19.30

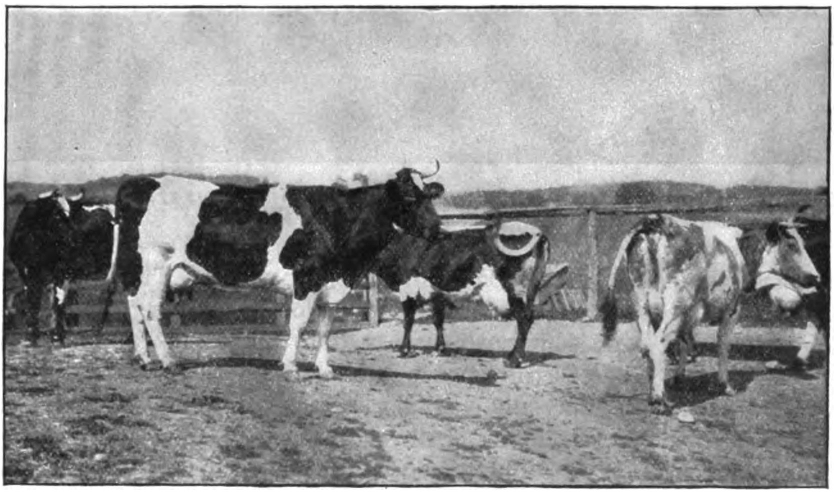

FIG. 64.— *Five cows in herd 17 whose best yearly milk records average 14,018.9 pounds (Table 12)*

Certain expenses were favorable to the herd. There was a short haul, judiciously provided for. The barn was inexpensive, but ample for all

purposes pertaining to the cows. However, labor and feed freely given have brought their reward, bearing out what is obvious — that under reasonable circumstances, good cows, rational feeding, and intelligent management are the foundation of economic milk production. If any one of these conditions is lacking, disastrous results are likely to follow.

Herd 41

In this herd of 27 cows, 7 were three years old and 3 were too old to be very productive; therefore the relative production of the herd as a whole is low. The data (given in Table 9, page 642) are of value as

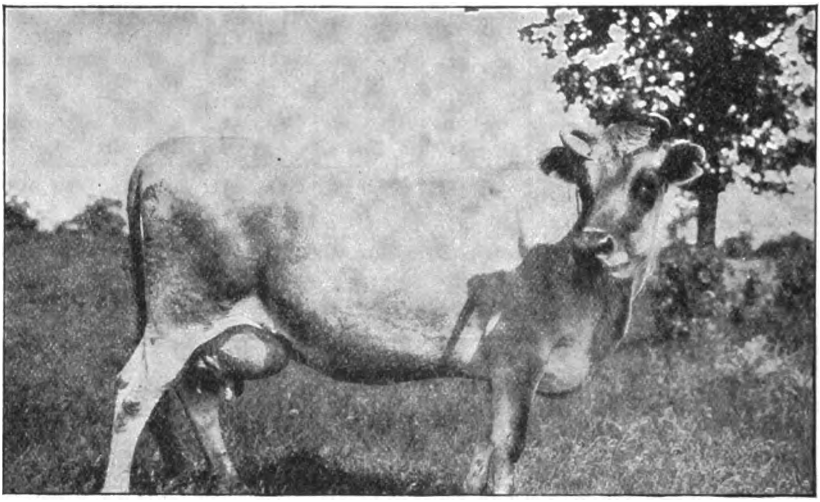

FIG. 65.— *Cow 1, herd 41. The best yearly record of this cow was 11,875 pounds of milk and 457 pounds of butter-fat (Table 10)*

illustrating economic production from moderate yields. The cows were registered and grade Jerseys, with production in keeping with their breeding. They were sufficiently well-bred to make good use of their food. The cost of feed corresponds closely with the average, but a very low fixed cost, especially for labor, reduces the net cost per cow. The owner made excellent use of an exceptional pasture, and, being a mature and experienced farmer, reduced the labor item without sacrificing production. The average profit per cow was $45. Milk was produced at 83 cents per hundred pounds and butter-fat at 17.3 cents per pound. The best cow gave 11,875 pounds of milk, containing 457 pounds of butter-fat, in a year. Her milk cost 58 cents per hundred pounds for production, and the butter-fat 15.2 cents per pound.

None of the four herds discussed are alike in breeding, scale of production, or personal supervision. With the exception of herd 3, they possess the elements of a paying enterprise, although herd 17 shows the best combination of factors for profit. In the case of most of the fifty-three herds studied, changing one factor, or at most two factors, in its management would change it from a losing or an indifferent business to one of definite profit.

WHY THE COSTS ARE LOW

Many of the local conditions and advantages surrounding the herds discussed in this study combine to give relatively low average costs. Pasture, which is one of the best and cheapest sources of nutriment, is used extensively. The general use of cheap coarse fodders about the farm, which could not be profitably marketed otherwise, together with the use of liberal amounts of farm-grown grains, has materially reduced the item of cost of feed. The investments in building and equipment are also relatively small. The labor charge, which covered care of all cows in the herd whether they completed their records or not, should be sufficient to offset any irregularities or losses incident to changing cows, in so far as these changes might affect the ultimate cost of the product.

The enthusiast, however, should be cautioned against seizing on these conclusions for one county with peculiar local advantages as answering the question for the whole State. It should be kept in mind that the cows here considered are above the average in production, and consequently are more economical producers. Under conditions prevailing in many other counties of the State, food costs would be doubled for the same scale of production, and other costs would increase from 20 to 40 per cent. This would make the cost of a quart of milk from the average cow considerably more than the producers receive for it.

SUMMARY

The following conclusions as to costs incident to milk production are based on a study of the individual cow, and the milk, butter-fat, feed, cash receipts, labor, investment records, and other data, per cow, for 834 dairy cows with full year's records in fifty-three dairy herds in Jefferson County. The results obtained from the study are true and correct under the conditions indicated in the text. The conclusions may or may not be applicable elsewhere.

1. Seven of the fifty-three herds were kept at a loss of $1335.71.

2. On the basis of net cost and actual receipts, 161 cows, or 19 per cent of the total number, caused a loss to their owners of $1799.87, or $11.18 per cow.

3. The average production was 6621 pounds of milk and 241 pounds of butter-fat.

4. The milk was produced at a net cost of $1.21 per hundred pounds, and the butter-fat at 33.3 cents per pound.

5. The average selling price of the milk was $1.52 per hundred pounds, the average profit was 31 cents per hundred pounds, and the net profit per cow was $20.39.

6. The average cost of feed per cow was $51.57, or 64 per cent of the average net cost of keep.

7. The net cost per cow was $80.24 and the receipts were $100.63.

8. The labor cost of caring for each cow was $23.12.

9. The average cost of delivering 100 pounds of milk 2.14 miles was 11.7 cents.

10. The profit from cows yielding 10,000 pounds of milk a year was 51 per cent greater than from those yielding 6000 pounds.

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The regular bulletins of the Station are sent free on request to residents of New York State.

Ithaca, New York, February 9, 1915

Director B. T. Galloway,
College of Agriculture,
Ithaca, New York.

Dear Sir:

In accordance with the terms of the Industrial Fellowship agreement with the C. W. Stuart Company, of Newark, New York, and with the terms of the Investigatorship agreement with the nursery firms of C. W. Stuart Company of Newark, New York, Chase Brothers Company of Rochester, New York, Brown Brothers of Rochester, New York, and Jackson & Perkins of Newark, New York, I beg to submit herewith a report of investigations of some important leaf diseases of nursery stock with the recommendation that it be published as Bulletin 358 of the Cornell University Agricultural Experiment Station.

The work has been done by Professor V. B. Stewart, and represents experimental work and investigations extending from the year 1909 to the present time. During the summer months the work has been done in the nurseries of the firms mentioned above; much of it in the C. W. Stuart Nursery at Orleans, New York, and the Chase Brothers Nursery at Honeoye Falls, New York.

Respectfully submitted,
H. H. Whetzel,
Professor of Plant Pathology.

CONTENTS

SOME IMPORTANT LEAF DISEASES OF NURSERY STOCK

VERN B. STEWART

INTRODUCTION

It is the purpose to discuss briefly in this bulletin the various diseases affecting the foliage of nursery stock as grown in New York State, and, as far as possible, to offer suggestions for prevention. The nursery business is a somewhat specialized industry, and only a very few students of phytopathology have had an opportunity to devote much of their attention to diseases as found in nursery plantings. This has been the situation particularly throughout the past fifteen years. Previous to that time some of the pioneer pathologists of this country conducted numerous investigations for the control of leaf diseases of nursery stock. Among these were B. T. Galloway, D. G. Fairchild, and F. L. Scribner, working for the United States Department of Agriculture. L. H. Pammel, of the Iowa Agricultural Experiment Station, also experimented on the control of various diseases appearing in the nurseries of Iowa. The work of these men covered a period of years and is of much importance, especially that of Doctors Galloway and Fairchild, who conducted most of their investigations in the nursery district around Geneva, New York. Many of the methods of control suggested by these investigators are still in use to-day, and have been very effective in reducing the annual losses suffered by nurserymen because of diseased stock.

The nursery business is one of the most important specialized agricultural industries of New York State. The growing interest in landscape gardening and the tendency toward more extensive orchard planting have caused a rapid growth in the nursery industry of this country. The figures recently published in this connection by the Division of Statistics, Bureau of the Census (1912), are of special interest. The total value of nursery products reported from 5582 establishments in 1909 was $21,051,000; this was an increase of 591 establishments, or 11.8 per cent, and $10,927,000, or 107.9 per cent, in ten years. In 1909 the Middle Atlantic States ranked first, with products valued at $4,355,000 as compared with $2,523,000 in 1899 — an increase of $1,832,000, or 72.6 per cent, during the decade from 1899 to 1909. Although the number of establishments reporting nursery products was greatest in the northeastern Central States, being here 1159, this section ranked fourth in value of products, being excelled by the Middle Atlantic, northwestern Central, and Pacific divisions. In percentage of income the Pacific States ranked

(1912) Press notice, Division of Statistics, Bureau of the Census. June 25, 1912.

first, with 377 per cent; the southwestern Central States second, with 179.4 per cent; and the south Atlantic States third, with 117.4 per cent.

The three States ranking highest in value of nursery products in 1909 were: New York, $2,751,000; California, $2,213,000; and Texas, $1,253,000. The order in 1899 was New York, Iowa, Illinois. An increase in value of nursery products is reported from all States except Maine, Vermont, Virginia, and South Carolina; no increase is reported from the District of Columbia. In the State of Washington the value of products in 1909 was almost twenty times as great as that in 1899.

The nursery business, like all industries, demands attention directed along certain lines that tend to promote its progress and advancement. The important problem confronting nurserymen of to-day is the production of the greatest amount of first-class stock per acre of land within the shortest period of time. The market sets certain standards of quality and size, and in order that a financial gain may be realized the development of this stock must be encouraged so that it will be marketable as soon as possible. Such conditions as weather, soil, amount of cultivation, and presence of certain destructive diseases, are some of the factors that influence the development of nursery plantings. Of particular importance is the effect of various plant diseases and insects. The stock may have developed very rapidly and be perfectly healthy, when within a very short time conditions may change and the plants become seriously injured or totally ruined by some destructive disease or insect.

The losses in the nursery caused by diseases are often very heavy. Some diseases, such as fire blight, completely destroy the stock attacked unless the disease is eradicated by cutting out the affected parts. Other diseases affect only the foliage and are a menace to nursery stock by causing the leaves to fall prematurely, thus retarding the development and growth of the plants. Not only does this condition make it necessary for a longer time to elapse before the stock is salable, but premature defoliation also prevents proper maturation of the trees and makes them less able to withstand winter injury, adverse conditions encountered in storage, and the like.

The control of leaf diseases in nursery stock offers a problem for special consideration. Methods commonly practiced for the prevention of diseases of older and maturer plants are in many cases not applicable to the smaller stock in the nursery, while, on the other hand, in many cases certain methods of control can be carried out in the nursery which could not be used in the treatment of mature plants. The latter condition is particularly emphasized in the control of diseases affecting such stock as roses or currants. Applications of fungicides that mar the beauty of the rose blossoms are permissible only in the nursery, where

blossoms are not desired owing to their tendency to check the development of the young bushes. Currants in the nursery can be sprayed at any time; on the other hand, for older bushes it is not desirable to spray with a fungicide that will be apparent on the fruit when it is picked for the market.

The prevalence of certain diseases also differs with the age of the host plant. One of the most important diseases of orchard trees is the well-known scab, and every year it is necessary to spray as a protection against this, while in the nursery the same disease is seldom of any great economic importance. The susceptibility or resistance to disease of seedlings and budded stock of different ages is likewise worthy of consideration. Some diseases may become localized and be exceedingly prevalent in one nursery, while in another nursery district the same diseases cause but little damage. A satisfactory means of applying the spray mixture also demands special attention. All these factors are of much significance in the control of nursery diseases. They require methods particularly applicable to the conditions that exist, and in many respects differ from the ordinary procedure followed by the pathologist in his attempt to check these destructive parasites.

A large proportion of the leaf diseases affecting nursery stock are caused by the low group of plants known as fungi. Many species of fungi are parasitic, living on other plants from which they obtain their food and nourishment. The plant attacked by the parasite is commonly designated as the host. In an effort to obtain food, the activities of the fungi are usually such as to cause severe injury to the cells of the host plant and certain parts of the plant tissue are killed. When a fungus attacks the foliage, so much of the tissue may be injured that the leaves are no longer able to function in the manufacture of food for the plant and fall prematurely to the ground.

The usual means of protecting the foliage from attacks of these parasitic fungi is by covering the leaf surface with a fungicide, or spray mixture which is highly poisonous to the fungus. In spraying for the prevention of a disease it is necessary to keep in mind the relations existing between the host plant and the fungus causing the disease. In general, conditions of rainfall and temperature that influence the host affect also, to some extent, the activities of the fungus. Each rainy period of an ordinary summer season favors the growth of the host plant, since sufficient moisture is supplied for its development. On the other hand, wet weather also affords necessary conditions for the parasite. Unless moisture is present, the fungus spores, by means of which the parasite is propagated, are unable to germinate and produce infection when they fall on the leaves of the host plant.

Various kinds of spores require different amounts of moisture, but in general the fungi causing leaf diseases produce the greatest damage when a rainfall is followed by damp, cloudy weather for a period of twenty-four hours or longer. Drops of water falling on the leaves supply the spores with moisture for germination. The spore sends out a germ tube, which penetrates the leaf tissue within a few hours, and is soon able to extract its nourishment from the affected tissue and thus continue its growth.

After the spore has germinated and the germ tube has gained an entrance into the tissue, it is impossible to check the fungus. For the prevention of the disease, therefore, it is necessary to check the parasite in its attacks before it can establish itself in the host. It is by means of the fungicides applied to the healthy foliage before the conditions are suitable for the development of the fungus, that the latter is kept in check. When the spore germinates, the germ tube comes in contact with the poison, is killed, and thus fails to produce an infection.

Unsuccessful attempts to control certain diseases may often be due to failure to apply the spray mixture at the proper time. It is necessary to make the application at such intervals as will afford the greatest protection to the foliage throughout the growing season. A thorough spraying will protect the leaves for a considerable length of time, but it will not be of any value to the foliage developed subsequently. As long as growth continues the new leaves must be sprayed shortly after they appear. The rate of growth of the host plant, along with the weather conditions, determines the time for the applications of the fungicide. With prolonged periods of dry weather the plants do not grow so rapidly and the time interval between certain sprayings may be somewhat lengthened as compared to seasons when wet weather prevails.

It is of extreme importance to remember that in order to insure protection to new foliage, the fungicide must be applied *before* the rains, not after. The *fungicides are not washed off by the rains*, but, on the other hand, when the leaves are thoroughly covered, the poisonous compound acts as a preventive against the attacks of the germinating spores during damp, cloudy weather. Spraying should never be deferred or discontinued for fear that the fungicide will be washed off; it dries rapidly, and when dry a sufficient amount remains to afford protection against the fungous parasite even after continued heavy rainfall.

SPRAY MIXTURES

Bordeaux mixture has been the standard spray mixture used in the nursery for many years and is very effective against most leaf diseases. The mixture may be made by the grower, or it may be bought on the market in the prepared form known as bordeaux paste or powder. Home-

made bordeaux mixture is preferable, since it remains in suspension somewhat longer than the market mixture, and it also has better sticking qualities when applied to the foliage. Considerable objection to the use of bordeaux mixture has been raised from time to time owing to the injury or burning of certain foliage, particularly that of plums. Serious damage to plum nursery stock has been reported occasionally. The formula most commonly used for making bordeaux mixture is 5 pounds of stone lime, freshly slaked, and 5 pounds of copper sulfate (blue vitriol), to 50 gallons of water.

Lime-sulfur solution has been substituted in recent years for bordeaux mixture in the control of several diseases. This solution also may be made by the grower, but unless ample facilities are at hand it is preferable, for nurserymen at least, to use commercial lime-sulfur solution, which can be bought in a concentrated form. This solution may also cause burning of the foliage unless care is taken not to apply the solution in too concentrated a form. Lime-sulfur solution is easier to handle than bordeaux mixture and it has proved more effective in the control of certain diseases, especially the mildews. The strength of lime-sulfur solution to be used varies, depending on the host plant and to some extent on the fungus causing the disease.

The addition of granulated iron sulfate to lime-sulfur solution has been of value in some cases. The iron sulfate reduces the danger of burning, and the mixture formed has better sticking qualities, especially if it is applied at a low pressure or with a gas spraying machine. Iron sulfate appears to slightly reduce the efficiency of lime-sulfur solution for some diseases by changing the composition of the mixture, but this has not been of sufficient importance to be considered. On the other hand, the addition of iron sulfate apparently increases the efficiency of the solution in the control of certain mildews, such as those that attack apple and rose stock. Iron sulfate added to lime-sulfur solution causes a black, muddy precipitate to be formed. This precipitate, which gradually settles to the bottom, contains precipitated sulfur, iron sulfide, and calcium sulfate. It is the precipitated sulfur in the mixture which has the valuable fungicidal properties.

Dusting with sulfur is effective in checking certain diseases, such as some of the mildews. Considerable experimental work has been conducted in order to determine the value of dusting for other orchard diseases; but the results thus far obtained do not warrant the adoption of this method for the general control of nursery diseases, although the perfection of a dust mixture would eliminate many of the difficulties encountered at the present time in the attempt to check these diseases in the nursery.

SPRAYING MACHINES

One of the important problems confronting nurserymen is a satisfactory means of applying spray mixtures. An apparatus is desirable which will apply the spray with sufficient force and with the least inconvenience, permitting the work to be done with considerable rapidity and as economically as possible.

Numerous hand sprayers (Fig. 86, page 699) are in use which can be used for small plantings, but there is no power machine on the market that

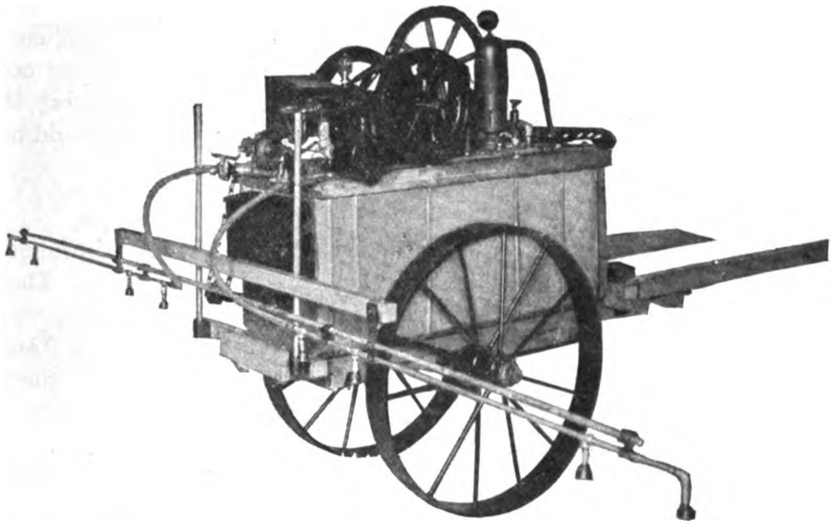
PHOTOGRAPH BY D. GUNN

FIG. 66.— *A two-horse gas-power sprayer for spraying all stock below six feet in height*

is entirely satisfactory for nursery work. It has been difficult to construct a machine that can be transported over tall stock and at the same time will be practicable. The practical sprayer for the nursery is a two-horse-power machine built to spray at least four rows of large stock and equipped with a container that will hold at least 75 gallons of the spray mixture. It should be easy to transport, and should be provided with a device that will furnish the necessary pressure for spraying. The power for spraying machines has usually been supplied by traction, gasoline engines, compressed air tanks, or compressed carbonic acid gas.

A two-horse gas-power machine for spraying all stock below six feet in height is illustrated in figure 66. This machine straddles two rows, and has two 50-gallon steel tanks suspended between the rows as containers of the spray mixture. The power is furnished by compressed carbonic acid gas. The gas is procured in steel drums and the spraying may be done with any pressure desired.

The greatest objection to this sprayer is its bulkiness and the effect of the carbonic acid gas on certain of the spray mixtures, such as lime-sulfur solution. The gas precipitates the sulfur in the lime-sulfur solution, reducing the efficiency of the solution as an insecticide when used for



PHOTOGRAPH BY W. C. AKINS MACHINE COMPANY

FIG. 67.— *A sprayer built to run between nursery rows. The width of the sprayer from hub to hub is twenty-eight inches. The power is furnished by a gasoline engine*

San José scale or other scale insects. On the other hand, the carbonic acid gas does not affect the fungicidal properties of the solution; the precipitated sulfur is practically as effective as the lime-sulfur solution, but it does not stick so well to the foliage. The sticking qualities, however, can be increased considerably by the addition of iron sulfate.

The machine illustrated in figure 67 is a sprayer constructed to go between the nursery rows. The width from hub to hub is twenty-eight inches, giving a clearance in the nursery row of fourteen inches. One horse, or two horses driven tandem, can be used. The containing tank holds 75 gallons and the power is furnished by a gasoline engine. Four rows at a time can be sprayed, and the spray boom, with two or

three nozzles to a row, is adjustable to any height necessary. When the machine is used for dormant spraying, trailers may be substituted for the spray boom. Three or four attachments of hose, from twelve to twenty feet in length, with nozzles, are carried by men who follow behind the sprayer, each man with a trailer spraying a single row. The trailers make it possible to cover the trees more thoroughly, and are especially desirable in spraying to prevent peach leaf curl and San José scale.

This sprayer is an improvement on the machine illustrated in figure 66, in that it is not so cumbersome and is less expensive to operate, and in that the spray mixture is not affected by the carbonic acid gas when the latter is used for pressure. On the other hand, this sprayer has proved to be top-heavy when used on unlevel ground. This difficulty could undoubtedly be overcome by changing the dimensions of the container and mounting it on a four-wheeled platform. By reducing the height of the container and increasing the length, the machine would not upset so easily.

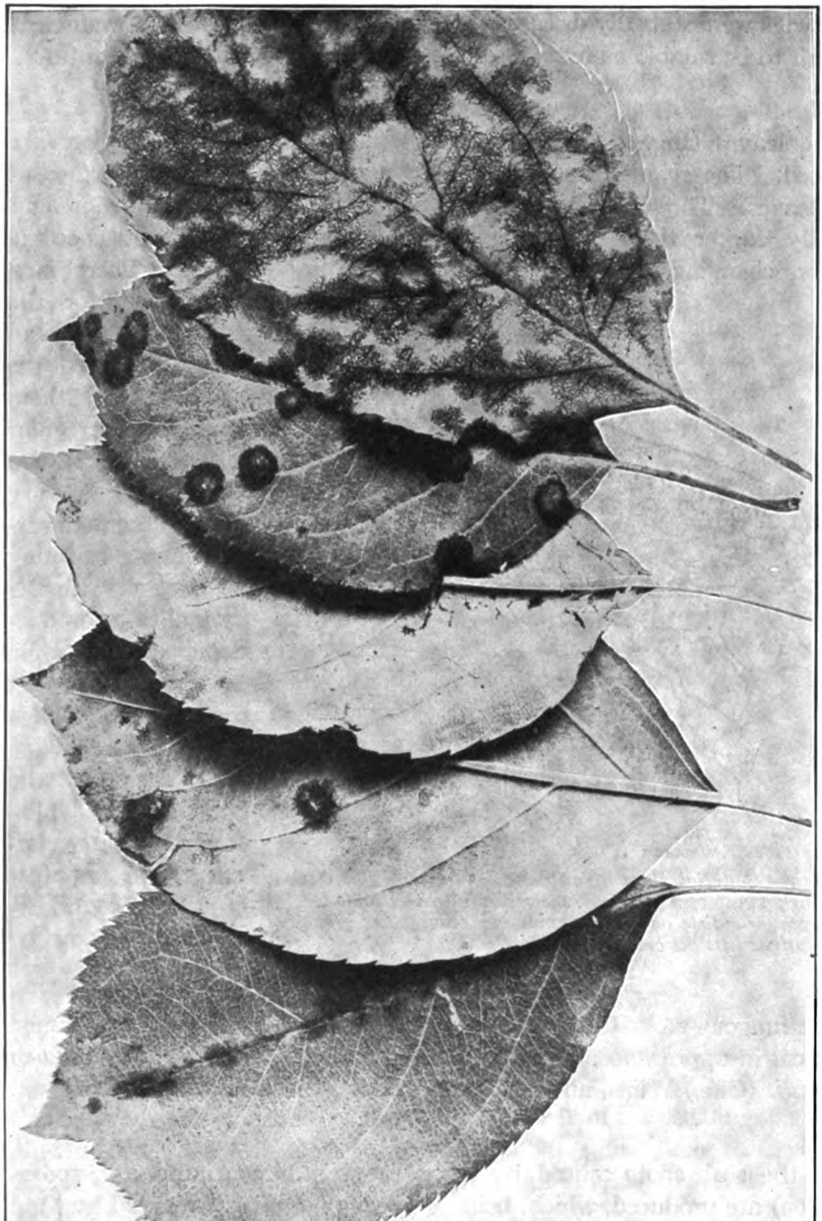
APPLE SCAB AND PEAR SCAB

The diseases known as scab are called also black spot, scurf, or the fungus. The name *scab* is used almost exclusively in the United States. These diseases apparently exist in every country where apples and pears are grown commercially. They are widely distributed in the United States, and in seasons favorable to them the annual losses in New York orchards due to apple scab alone are estimated by Wallace (1913) at over three and one-half million dollars.

In the nursery, pear scab commonly affects the Flemish pear buds, and when conditions are favorable to the disease almost complete defoliation of the trees may result in midsummer. The twigs and the young shoots also are usually affected, causing the branches to make a stunted growth. Several blocks of two-years-old pear stock have been observed by the writer, of which the Flemish variety was so badly affected by the scab that only from about five to ten per cent of the trees calipered first-class (XXX) when dug in the autumn. The other varieties were not noticeably affected by the disease.

The apple scab is most commonly found in the nursery on the Transcendent crab. Frequently considerable defoliation in this variety may result from the disease. Other varieties of apples are occasionally affected. In the season of 1913 there was a severe epiphytotic of the apple scab disease in one of the large nurseries of New York State, and all varieties were somewhat affected. The disease was most serious in the two-years-

(1913) Wallace, Errett. Scab disease of apples. New York (Cornell) Agr. Exp. Sta. Bul. 335 : 541–624.



PHOTOGRAPH BY E. WALLACE

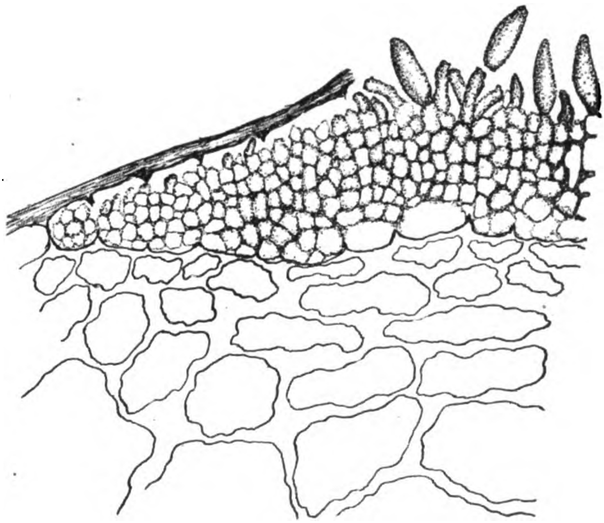
FIG. 68.—*Apple-scab disease on leaves. The second and third leaves from the left show the lesions on the under surface*

old budded McIntosh trees. Heavy defoliation resulted, and shoots and twigs were so badly diseased that very few of the trees made sufficient growth to be salable as first-class (XXX) stock when dug in the autumn.

Symptoms

The leaves (Fig. 68) and the fruit, and occasionally the twigs, are affected. The scab is likely to appear earliest on the under surface of the leaves. The diseased area is at first olivaceous in color and slightly darker than the normal leaf. Later the scab spots become darker, changing to brown and finally to nearly black. There is a tendency for the lesions to extend along the veins of the leaf, making them somewhat irregular in appearance. When the disease is very pronounced both surfaces of the leaf may be covered with the dark olive-colored lesions, and in some cases curling or distortion of the foliage may result.

On the twigs the bark becomes blistered, and later ruptured in places, causing a scurfy appearance.



PHOTOGRAPH BY E. WALLACE

FIG. 69.— *Conidial stage of apple-scab fungus. The section, through a scab spot on a leaf, shows the fungous stroma located beneath the cuticle and in the epidermal cells. The growth of the fungus lifts the cuticle of the leaf*

Cause

The fungous parasites causing the apple scab and pear scab are almost identical in appearance. The species on the apple is known as *Venturia inæqualis* (Cke.) Wint., and that on pears as *Venturia pyrina* Aderh.

Life history

On the scab spots caused by these fungi a large number of spores (Fig. 69) are produced, which, being very small, are disseminated by wind and rain. Falling on the fruit and the leaves of the host plant, these spores produce new infections when moisture is present and are a means of propagating the fungi throughout the summer.

On the diseased leaves that fall to the ground in autumn, special fruiting bodies (perithecia) are produced, which are resistant to cold and bridge the fungi over winter. In the early spring numerous sac-like bodies, asci, bearing eight spores, are developed in the perithecia. These ascospores are discharged during periods of damp, cloudy weather about the time when the leaves begin to open, and, carried by wind and rain, they fall on the newly developed foliage, where they produce the first infection of the season. From twelve to fourteen days after the spores attack the foliage the characteristic scab lesions begin to appear.

Control[1]

Bordeaux mixture and lime-sulfur solution are both effective for the control of the scab diseases on apple and pear. In recent years lime-sulfur solution has been used almost exclusively by orchardists for apple scab. The standard strength used is 1 to 40. In many cases bordeaux mixture causes some injury by burning fruit and foliage; but, on the other hand, for pear scab it is advisable to use bordeaux mixture, since lime-sulfur solution occasionally causes severe burning of pear foliage when used at a strength that will control the scab.

For nursery stock the first spraying should be done soon after the first new leaves are put forth. This application should be followed by at least two more sprayings at intervals of from two to three weeks. If the season is very wet, one or two more applications are advisable in most instances.

As a general recommendation for the nurseries of New York State, it is not considered necessary to spray varieties of pears for scab except the Flemish. The trees of this variety are so commonly affected that spraying each season is beneficial. In most nurseries it is not necessary to spray each year for apple scab, but in some instances spraying would be exceedingly beneficial. Where the disease is commonly observed on certain varieties of apples such as Transcendent crab, spraying is advisable.

APPLE POWDERY MILDEW

Cherry, plum, pear, and quince stock are occasionally affected by powdery mildew, but this disease is most commonly observed in the nursery on the foliage and the young shoots of the apple seedling stock. When it appears early in the summer, the growth of the seedlings is checked and the bark does not peel readily at budding time. The budded apple stock is sometimes affected and severe epiphytotics of the disease have been known to occur in bearing apple orchards.

[1] Dusting with dry sulfur for scab control (See New York [Cornell] Agr. Exp. Sta., Bul. 354, 1915, by Donald Reddick and C. R. Crosby) has proved effective to a considerable degree in certain experimental orchards where it has been tried, but as yet the results obtained do not warrant the general adoption of this method as a means of preventing scab.

Symptoms

The foliage and the young twigs are affected, and in extremely rare cases the disease occurs on the fruit of apples. The grayish white, feltlike areas are commonest at first on the underside of the leaf, and vary in size from a minute speck to an inch in diameter; later the mildew may appear on the upper surface, involving the entire leaf. The diseased leaves are stunted, are somewhat narrower in width than the healthy leaves, and have a tendency to crinkle and curl up.

Affected shoots are much shorter than they would be normally. There is a shortening of the internodes, and in many cases an increase in thickness of the diseased twigs may be noticed. Small black specks are commonly observed in the white areas on the twigs.

The ends of the diseased shoots die back in winter, causing the production of numerous lateral shoots in the following spring. The old grayish white patches of mildew are often very apparent on the twigs throughout the winter.

Cause

The disease may be caused by either of two fungous parasites, *Podosphæra oxyacanthæ* (DC.) de Bary or *Podosphæra leucotricha* (E. & E.) Salm. These two species are very closely related, and only a microscopic examination of the sexual stage (the black specks referred to above) enables one to definitely distinguish them. *P. oxyacanthæ* is found very commonly on cherries, but, in the United States at least, the organism attacking apples is in the greater majority of cases *P. leucotricha*. F. C. Stewart (1910) examined specimens of apple mildew from various sections of New York State and all of them proved to be *P. leucotricha*. At the same time the writer also examined specimens of the apple mildew collected in several nurseries of the State, and all were of the same species, *P. leucotricha*. Ballard and Volck (1914) state that the apple powdery mildew in the Pajaro Valley of California is caused by *P. leucotricha*.

Life history

The grayish, feltlike patches of mildew on the leaf or the shoot consist of a tangle of fine threads, or strands, of the fungus. This loosely interwoven mass of threads is known as mycelium. From certain strands of the mycelium, stalks are sent up which bear large numbers of conidia, or summer spores (Fig. 94, page 713). The spores, being very minute, are carried by wind and rain to other leaves, where under favorable conditions they germinate and produce new patches of mildew. The fungus obtains

(1910) Stewart, F. C. Notes on New York plant diseases. New York (Geneva) Agr. Exp. Sta. Bul. 328: 320–321.
(1914) Ballard, W. S., and Volck, W. H. Apple powdery mildew and its control in the Pajaro Valley. U. S. Agr. Dept. Bul. 120: 1–26.

its nourishment by sending suckerlike bodies, haustoria, into the epidermal cells of the leaf. After midsummer reproductive bodies, known as perithecia (Fig. 70), are also produced in the mass of mycelium. These perithecia appear to the naked eye as the small black specks previously mentioned, and they serve to bridge the fungus over winter. In the following spring or early summer each perithecium discharges an ascus (Fig. 70), which contains eight ascospores. Falling on the newly developed foliage, the ascospores germinate and produce the first infections of the season, resulting in the appearance of the mildew a few days later.

Ballard and Volck (1914) and other investigators are of the opinion that the fungus lives over winter in the dormant buds also. The following is quoted from Ballard and Volck (page 9 of reference cited): "Careful observations have led the writers to the conclusion that in the Pajaro Valley this method [by means of perithecia] of bridging over the winter season amounts to practically nothing in the matter of starting the first infections of the following year. It may be that relatively a very small percentage are established by this means, but the really important source is in what the writers have termed the dormant-bud infections. It can be easily seen that in such serious twig infections ...., the mildew growing over the surface of the shoots has an excellent opportunity to work its way in between the bud scales and penetrate both the lateral and terminal buds. This actually happens, and within these buds the mildew passes the winter in a dormant condition. The following spring, as the infected buds begin to open, the mildew commences to grow and keeps pace with the development of the new twigs."

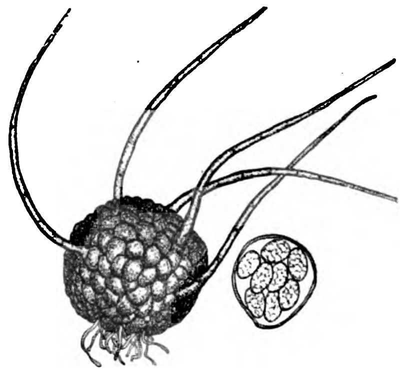


FIG. 70.—*Perithecium of the apple mildew fungus, showing the two types of appendages. Within the perithecium is a single ascus which contains eight ascospores (shown at the right)*

Control

Bordeaux mixture and other copper sprays are not satisfactory fungicides for the control of most mildew diseases (Galloway, 1889). This is particularly true of the apple powdery mildew (Fairchild, 1893). Lime-sulfur solution is effective to a certain degree, but the addition of iron

(1889) Galloway, B. T. Experiments in the treatment of pear leaf-blight and the apple powdery mildew. U. S. Agr. Dept., Veg. Path. Sec. Circ. 8:1–11.
(1893) Fairchild, D. G. Experiments in preventing leaf diseases of nursery stock in western New York. Apple powdery mildew. Journ. myc. 7:256.
(1914) Ballard, W. S., and Volck, W. H. Apple powdery mildew and its control in the Pajaro Valley. U. S. Agr. Dept. Bul. 120:1–26.

sulfate makes a mixture that is more satisfactory for the control of the disease. The precipitation caused by the iron sulfate converts the sulfur into a more finely divided form, which apparently has a better covering power and also sticks better to the foliage than does the lime-sulfur solution alone.

Lime-sulfur, 1 gallon to 50 gallons of water, plus 3 pounds of iron sulfate, has proved satisfactory for the control of apple powdery mildew in the nurseries of New York State. The first application should be made soon after the seedlings have developed the first new shoots. Three or four subsequent sprayings should be made at intervals of from two to three weeks.

In some seasons apple nursery stock, in New York State at least, is practically free from the mildew, while in other years the disease is very destructive. Therefore the number of sprayings required to keep the mildew in check depends on the season, and the control methods should be in accordance with the conditions that exist. Where the disease is prevalent an effort should be made to keep as much as possible of the new growth covered with the spray.

THE YELLOW-LEAF DISEASE OF CHERRY AND PLUM

Leaf blight, commonly known also as yellow leaf, or shot-hole, of plums and cherries, is one of the most important of the diseases affecting nursery stock. It was first reported in Europe in 1884 on *Prunus padus*, and has been common there on both sweet and sour cherries for the past twenty years. In America the disease has been reported on nearly all species of Prunus, both wild and cultivated. It is found in all the nursery districts of the United States where cherry and plum stock is grown, and may be very destructive to nursery trees when weather conditions are favorable.

Occurrence on different hosts

Usually the disease is found in abundance on the sweet cherry, *Prunus avium*, and on the wild chokecherry, *Prunus virginiana*. It is common on sour cherries, *Prunus domestica*, *Prunus institia*, and *Prunus spinosa*. The leaves of *Prunus serotina* also are known to have been affected.

In the nurseries of New York State the susceptibility of cherry and plum seedlings to the disease is of considerable importance. Mazzard cherry seedlings are very susceptible, and often they are so badly defoliated that it is impossible to bud the trees. Mahaleb cherry seedlings are affected to some extent, but ordinarily the damage is less than on mazzards. Myrobalan plum seedlings show a considerable degree of resistance and, at least in New York State, are seldom affected.

The varieties of sweet cherries are more seriously affected than are the sour cherries. Often, however, the disease is very destructive to all varieties of cherries and may cause a heavy loss of foliage. Varieties of European plums also may be defoliated completely by the disease in a season of abundant rainfall (Stewart, 1914). Japanese plums are more resistant, and the disease is of little importance on these varieties.

Symptoms

The leaves, the fruit, and the fruit pedicels may be affected, but generally the lesions are confined to the foliage and their appearance

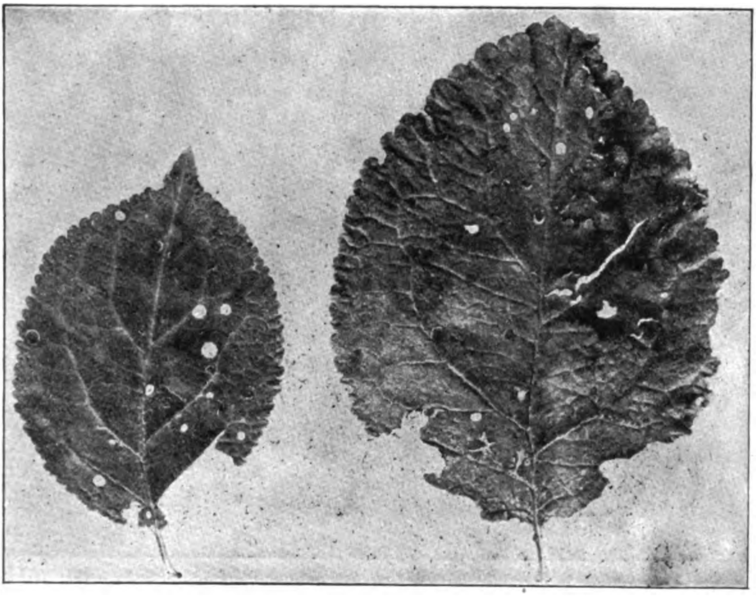


FIG. 71.— *Shot-hole effect on plum leaves affected with the yellow-leaf disease*

on the fruit is rather uncommon. The disease is first noticed in the latter part of May or in early June. On certain hosts it becomes very evident because of the shot-hole appearance of the leaves, which is brought about by the dropping-out of the circular areas of affected tissue (Fig. 71). The shot-hole effect is commonest on plum varieties, in which the perforations may be so abundant that, owing to the dropping-out of the diseased areas, only remnants of the leaves are left. Infections on the Japanese plum varieties are of a shot-hole nature, but there is practically no defoliation as in the case of the European plum varieties. It is believed

(1914) Stewart, V. B. The yellow-leaf disease of cherry and plum in nursery stock. New York (Cornell) Agr. Exp. Sta. Circ. 21 : 1–10.

that the larger part of the shot-hole effect on these varieties is caused by an insect.

On the leaves of cherries the diseased spots do not drop out so readily. They first appear on the upper side of the leaf as slightly discolored areas, usually not exceeding an eighth of an inch in diameter and more commonly about half that size. Later, after a period of seven to ten days, they become definite lesions, dark red or reddish brown in color. The infection may be confined to a small section of the leaf, but in many cases the red spots indicating the diseased areas are thickly scattered over the entire

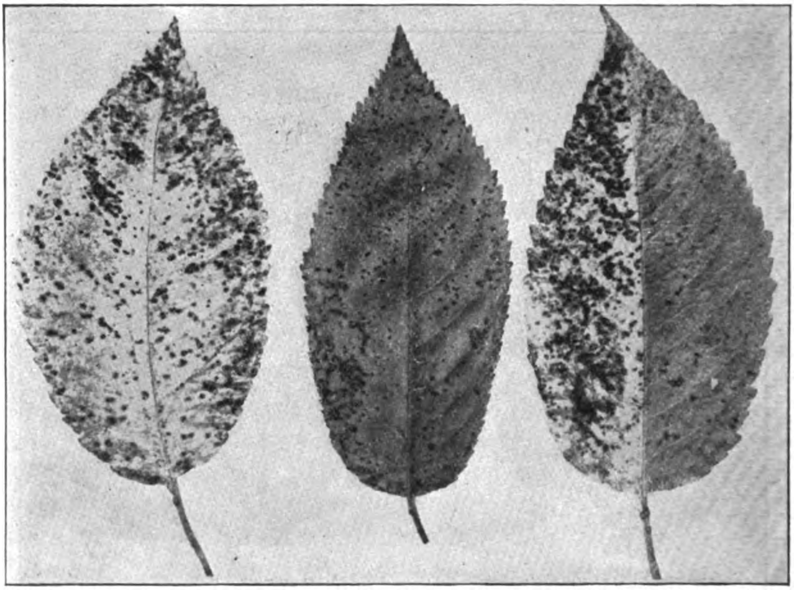


FIG. 72.—*Sweet-cherry leaves affected with the yellow-leaf disease, showing the dark red spots and also the yellow discoloration*

leaf (Fig. 72). In the advanced stages a yellowing of the affected foliage may occur and the leaves may fall prematurely.

The same yellowing sometimes appears on plum leaves, but never so abundantly as on sweet-cherry foliage.

Particularly in periods of wet weather, small, white, velvety pustules may be observed on the undersides of the leaves, opposite the discolored spots. Occasionally these pustules appear also in the center of the lesions on the upper side of the leaf.

Cause

In 1884 P. A. Karsten described the organism *Cylindrosporium padi*, and the yellow-leaf disease on *Prunus padus* in Europe was attributed

to this fungus. Higgins (1913) discovered the sexual stage of the Cylindrosporium on *Prunus avium* and named the fungus *Coccomyces hiemalis*. Further studies by Higgins (1914) show that there are at least three species of Cylindrosporium parasitic on species of the genus Prunus. The morphological differences of the sexual forms, along with cross inoculations, led Higgins to make the following distinctions:

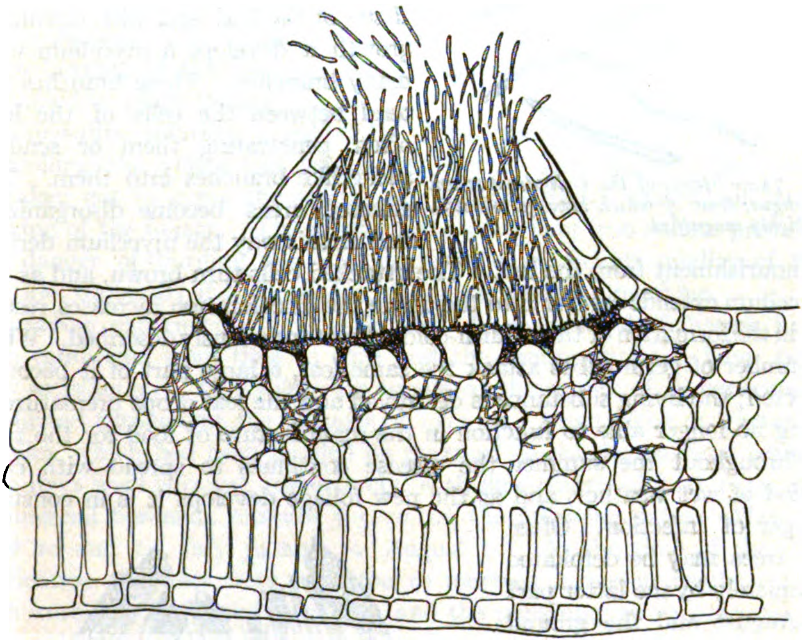


FIG. 73.— *Cross section of cherry leaf through an acervulus of the Cylindrosporium fungus. The epidermal cells of the leaf have been pushed up and broken, permitting the spores to escape*

Coccomyces hiemalis Higgins on *Prunus avium*, *P. cerasus*, and *P. pennsylvanica*

Coccomyes prunophoræ H. on *Prunus americana*, *P. domestica*, and *P. institia*

Coccomyes lutescens H. on *P. serotina*, *P. virginiana*, and *P. mahaleb*

Life history

With the active growth of the fungus in the leaf tissue, the mycelial threads of the fungus form a closely packed mass near the surface of the leaf, resulting in the formation of a fruiting body (Fig. 73). The number

(1913) Higgins, B. B. The perfect stage of Cylindrosporium on Prunus avium. Science 37 : 637–638.
(1914) Higgins, B. B. Contribution to the life history and physiology of Cylindrosporium on stone fruits. Amer. journ. bot. 1 : 145–173.

of spores produced is usually very great, and on being pushed out on the undersurface of the leaf they form the white pustules previously described. The spores, being very minute, are easily carried to the leaves by the wind and rain, and are thus disseminated over a considerable distance. Falling on a leaf, the spore germinates (Fig. 74) if moisture is present, the germ tube penetrates the tissue of the leaf, and with continued growth it develops a mycelium with many branches. These branches extend between the cells of the leaf, often penetrating them or sending suckerlike branches into them. The affected areas become disorganized, and in this way the mycelium derives its nourishment from the leaf. The attacked cells turn brown, and as the mycelium extends farther into the tissue the discoloration increases, resulting in the formation of the reddish-colored spots previously described. When a number of germ tubes attack the same leaf, a large part of it becomes affected; the living substance is destroyed and the leaf drops prematurely, being no longer able to function in the manufacture of food for the tree.

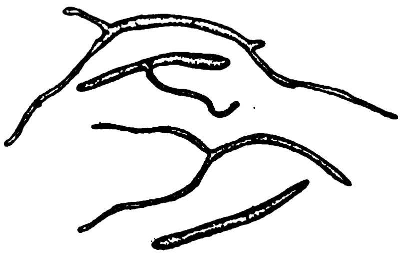


FIG. 74.— *Spores of the Cylindrosporium fungus, some of which have germinated. Highly magnified*

Throughout the summer the disease continues to spread with each period of wet weather, and as the new foliage develops it is in constant danger of infection. Often the trees may be defoliated completely by the latter part of August and the ground may be covered with diseased leaves. It is in these old, affected leaves that the fungus lives over winter. By the formation of the sexual fruiting body (Fig. 75) within the leaf tissue the organism is able to withstand the severe cold weather of the winter months. During periods of abundant rainfall in the following spring, when the trees are developing the first new leaves, these specialized fruiting bodies (known as apothecia) discharge large quantities of spores. Some of these spores are carried by the wind or by scattering drops of rain to the new foliage, where they produce the first

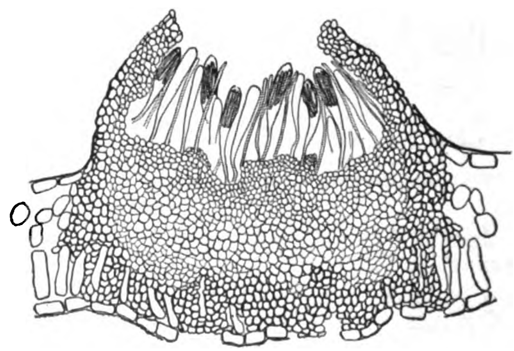


FIG. 75.— *Cross section of sweet-cherry leaf through an apothecium of the fungus Coccomyces hiemalis, showing the saclike bodies (asci) with needle-shaped ascospores*

infections of the year and the characteristic diseased spots become apparent about seven to ten days later. According to Higgins (1914) the apothecial conidia produced in many cases in the old apothecium are also able to produce infection. The writer also has commonly observed these conidia in old apothecia.

Control

Bordeaux mixture or lime-sulfur solution may be used for the control of the disease. The former, while very effective (Fairchild, 1893), may cause burning of the foliage. This is especially true when the mixture is applied to plum foliage.

Lime-sulfur solution, 1 gallon to 50 gallons of water, is effective in controlling the yellow-leaf disease on cherries and plums. Care must be taken not to apply the solution at such a strength that it will cause burning of the foliage. The addition of 3 pounds of iron sulfate prevents the danger of burning and also increases the sticking quality of the solution, especially if it is applied with a gas spraying machine.

Spraying experiments for the control of the yellow-leaf disease have been conducted from time to time and the results obtained have been very satisfactory. In Table 1 are tabulated the results of an experiment conducted throughout the summer of 1911 on a small block of Tartarian cherries, which had been budded on mazzard stocks the previous season. Two rows were sprayed, respectively, with lime-sulfur solution 1–50, and commercial bordeaux mixture 5–5–50, on the following dates: May 28, June 10 and 24, July 14 and 30, August 12. At the time of the first application the trees were from ten to fourteen inches in height. Two rows were left unsprayed as checks, and the remaining two rows received one application of lime-sulfur 1–50 on June 24.

Previous to the spraying of June 24 very little infection had occurred, owing to the dry weather conditions. Continued heavy rains followed the spraying of June 24 and conditions were very favorable for abundant infection. The application just previous to this infection period was most effective in keeping the yellow-leaf disease in check. On August 24 the first fifty-three trees of one row in each plat were measured for caliper and the measurements are recorded in Table 1. For each caliper measurement the percentage is also recorded. The average height of sprayed trees was five feet; the unsprayed trees averaged about four and one-fourth to four and one-half feet in height. A comparison of the number of trees for each caliper in sprayed and unsprayed plats shows a considerable difference in favor of the sprayed trees. The failure of the com-

(1893) Fairchild, D. G. Experiments in preventing leaf diseases of nursery stock in western New York. Cherry leaf-blight. Journ. myc. 7 : 249–252.

(1914) Higgins, B. B. Contribution to the life history and physiology of Cylindrosporium on stone fruits. Amer. journ. bot. 1 : 145–173.

mercial bordeaux mixture to control the disease as well as the lime-sulfur solution was attributed to the poor sticking qualities of the mixture.

TABLE 1. A COMPARISON OF CALIPER MEASUREMENTS OF TREATED AND UNTREATED TARTARIAN CHERRY TREES FOR THE EXPERIMENT CONDUCTED IN 1911

Material used	Total number of trees	Caliper measurements in inches							
		3/8		1/2		9/16		5/8	
		Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Commercial lime-sulfur 1–50, six sprayings, row 1	53	16	30.2	29	54.7	5	9.4	3	5.7
Commercial bordeaux mixture 5–5–50, six sprayings, row 3...	53	19	35.8	28	52.8	4	7.5	2	3.8
Lime-sulfur 1–50, sprayed once, row 7	53	21	39.6	28	52.8	4	7.5	0	0
Untreated, row 5....	53	33	62.3	20	37.7	0	0	0	0

In Table 2 are shown the results of an experiment conducted throughout the summer of 1912. Three rows of first-year Tartarian cherry trees were sprayed with lime-sulfur solution 1–50, on the following dates: June 4 and 23, July 8 and 22, August 5 and 20. Two rows were left unsprayed as checks.

The data collected on September 19, 1912, showed a considerable increase in caliper of sprayed trees over unsprayed trees. One row of sprayed trees and one of the check rows were selected for the measurements and the first one hundred and twenty-five trees in each row were calipered. The average height of sprayed trees was four and three-fourths feet; the unsprayed trees averaged four to four and one-fourth feet in height.

When the measurements were taken for the above experiments the unsprayed trees had lost practically all of their leaves. For nurserymen

TABLE 2. A COMPARISON OF CALIPER MEASUREMENTS OF TREATED AND UNTREATED TARTARIAN CHERRY TREES FOR THE EXPERIMENT CONDUCTED IN 1912

Material used	Total number of trees	Caliper measurements in inches																				
		$\frac{1}{4}$		$\frac{3}{8}$		$\frac{7}{16}$		$\frac{1}{2}$		$\frac{9}{16}$		$\frac{5}{8}$		$\frac{11}{16}$		$\frac{3}{4}$		$\frac{13}{16}$		$\frac{7}{8}$		$\frac{15}{16}$	
		Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Lime-sulfur 1-50	125	0	0	5	4.0	4	3.2	11	8.8	24	19.2	32	25.6	31	24.8	9	7.2	6	4.8	2	1.6	1	0.8
Untreated	125	3	2.4	15	12.0	16	12.8	25	20.0	38	30.4	11	8.8	17	13.6	0	0	0	0	0	0	0	0

the increase in size of stock is certainly an important factor, but the effect of premature defoliation in unsprayed trees is also worthy of consideration. The early loss of foliage prevents proper maturation of the wood, and the trees are less likely to withstand the severe weather of winter. Winter injury occurs commonly on cherry and plum stock, and several cases have been observed in which the indications are that early defoliation in the previous summer favored the injury that occurred during the cold months.

It has been the custom of some growers to hold the shipment of mazzard seedlings, when received from Europe, in storage until late in the spring, after all the other seedling stock has been planted. If this method is followed the development of the seedlings when finally planted is very rapid, and they are more likely to make a sufficient growth for budding before they succumb to the attacks of the yellow-leaf disease. Certain nurserymen have suffered considerable loss due to injury of mazzard seedlings while in storage, however, and in general this means of warding off the disease does not seem to be practicable. The writer has conducted several experiments with reference to this question, and is led to conclude that the disease can be prevented more profitably by spraying. It is better to plant the mazzard stock when the other seedlings are put into the ground, and to prevent the early attacks of the yellow-leaf fungus by spraying. The first application should be made soon after the leaf buds open, and should be followed by at least four or five additional sprayings at intervals of from ten to fourteen days.

For the first-year buds the first application should be made when the buds are from eight to twelve inches in height. Subsequent sprayings should be in accordance with the weather conditions that exist. As a general practice, about five to seven applications throughout the summer, at intervals of two weeks, will suffice to keep the disease in check.

As a general recommendation for all stock susceptible to the yellow-leaf disease, the spray should be applied at such intervals as to keep as much of the new growth protected as is possible.

POWDERY MILDEW OF CHERRY

Powdery mildew of cherry is practically the same as the mildew that attacks apple stock, and according to Hein (1908) is occasionally found on plum, hawthorn, Spiræa, blueberry, and persimmon. In the nurseries of New York State the budded sour-cherry stock is usually most severely attacked, but often the disease is destructive on the sweet-cherry varieties and the mazzard stocks.

(1908) Hein, W. H. Two prevalent cherry diseases. Powdery mildew. Nebraska Insect Pest and Plant Disease Bureau, Bot. Div. Circ. 2 : 1–2.

The young, succulent leaves are particularly susceptible to the disease, and following a period of heavy rainfall a serious epiphytotic may occur.

Symptoms

The disease can generally be recognized by the characteristic upward rolling of the foliage, accompanied by a shortening and an increased thickness of the internodes of the twigs (Fig. 76). The young shoots, the tips of the branches, and the leaves are affected. The curled leaves are covered on the undersurface with a tangle of white, feltlike threads. Usually after midsummer, when the disease is well established and the leaves are severely infested, small black specks may be observed scattered on the surface of the feltlike mass on the underside of the leaf.

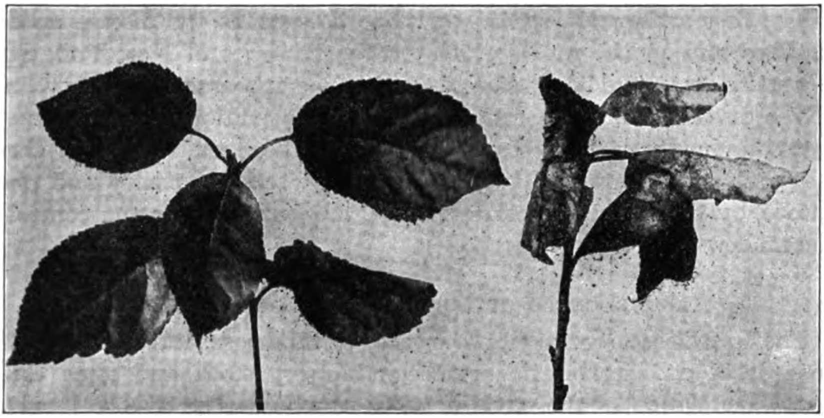


FIG. 76.—*Mildew on sour-cherry twigs: healthy twig on the left, diseased twig on the right. Showing the curled leaves, a shortening of the internodes, and an increased thickness of the twig*

The disease is caused by the fungous parasite, *Podosphæra oxyacanthæ* (DC.) de Bary. The same fungus may attack the apple also. The thick network of fungous threads form the white patches on the surface of the host tissue. From these mycelial threads stalks are sent up (Fig. 94, page 713), which bear the conidia. The conidia are produced in great abundance, and, being carried by wind and rain to healthy foliage, they serve to spread the parasite throughout the summer.

The fungus is bridged over the winter by means of the sexual stage (perithecia, Fig. 70, page 671), which appears on the white mycelium in late summer as the small black specks previously discussed. The perithecium contains an ascus with eight spores, and in the spring or early summer these spores are discharged. Lodging in a suitable place, such as on the surface

of a cherry leaf, the ascospores germinate by a germ tube and produce the first infections of the summer. Summer conidia are soon developed and new infections follow.

Control

Bordeaux mixture has been recommended by certain investigators for the control of this disease, but it is believed that better results are to be obtained with certain sulfur compounds. Dusting with dry powdered sulfur (flowers of sulfur) is also claimed by some to be effective; however, no satisfactory data are at hand to substantiate this claim.

The writer has obtained good control by the use of lime-sulfur solution diluted 1 to 50. The addition of 3 pounds of iron sulfate to 50 gallons of the mixture tends to reduce the possibility of injury to the foliage and also increases the sticking quality of the mixture.

The first application should be made as soon as the disease appears (Ballard and Volck, 1914), which for the nurseries of New York State is usually about the latter part of June. The appearance and prevalence of the disease varies, depending on weather conditions. From three to five sprayings may be necessary in order to keep the mildew in check. As a rule the sprayings for the yellow-leaf disease of cherry and plum, caused by the Cylindrosporium fungus, are sufficient for the control of the mildew also.

ANTHRACNOSE OF CURRANTS AND GOOSEBERRIES

The leaf disease commonly known as anthracnose, leaf blight, or leaf spot, is of considerable importance in nursery stock and often causes heavy defoliation of the stock in early summer. The disease is widely distributed and is known to occur in Europe, America, Asia, and Australia. In 1873 it was first reported in America as affecting black currants. Since that time it has been reported from various sections of the country, as affecting the cultivated varieties of currants and gooseberries. The disease is doubtless found in all sections of the United States where currants and gooseberries are grown.

Occurrence on different hosts

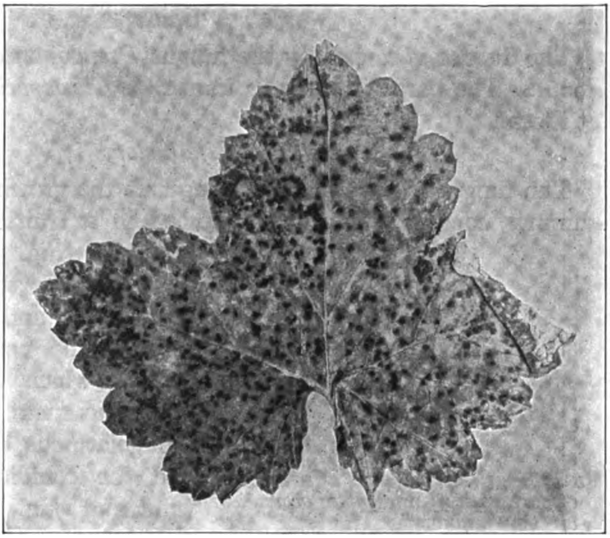
Anthracnose has been reported on several species of currants — including *Ribes nigrum*, *R. acicularis*, *R. aureum*, *R. prostratum*, and *R. rubrum* — and on gooseberries, *R. reclinatum* and *R. oxyacanthoides*. Black currants (*R. nigrum* and *R. aureum*) are usually more or less resistant and are seldom severely affected. Some differences are to be noted in the susceptibility of the varieties of red and white currants, though all may

(1914) Ballard, W. S., and Volck, W. H. Apple powdery mildew and its control in the Pajaro Valley. U. S. Agr. Dept. Bul. 120 : 1–26.

succumb to the disease. Stewart and Eustace (1901) found the Albert variety practically free from the disease when Fay and Victoria adjoining them were seriously affected. Observations made by the writer on August 4, 1914, in a large block of nursery stock, showed the following varieties completely defoliated: White Grape, Fay, Victoria, Wilder. The varieties Moore Ruby and Perfection were not so seriously affected. On September 1 very little foliage remained on any of the varieties.

As a rule, gooseberries are more resistant. The varieties Smith, Industry, and Whitesmith are more susceptible than the varieties Downing and Pearl. The Houghton variety is often severely affected.

Older bushes often suffer more than do first-year cuttings, a condition commonly observed in the nursery. The fact that the cuttings are usually planted on ground that has not been used for currant and gooseberry stock for some time and is perhaps some distance from the older plantings, no doubt accounts for the apparent resistance of the cuttings. Where cuttings have been planted in close proximity to old diseased bushes, they have been known to become diseased.



PHOTOGRAPH BY F. C. STEWART

FIG. 77.— *A leaf of red currant affected with anthracnose*

Symptoms

The disease first appears on the older leaves, which become covered on the upper surface with small, circular spots, dark brown in color and about one twenty-fifth of an inch in diameter. In the center of each spot there is developed a minute black area (Fig. 77). Soon the foliage turns yellow and diseased bushes may be recognized for a considerable distance. The petioles, flower stalks, young canes, and berries are affected; the black and slightly sunken spots on the petioles are readily

(1901) Stewart, F. C., and Eustace, H. J. An epidemic of currant anthracnose. New York (Geneva) Agr. Exp. Sta. Bul. 199: 63–80.

noticeable. The spots on the fruit stems may be one-half inch or so in length and extend half the distance around the stem. The pustules on the canes have never been found on wood more than one year old. Small black specks characterize the disease on the fruit; it is especially noticeable when the fruit of gooseberry bushes is affected.

The anthracnose disease is very often associated with the Septoria leaf spot, but the two diseases are readily distinguishable. The Septoria lesions (Fig. 79, page 687) appear dead and brown, and are larger, being one-eighth of an inch or more in diameter. On close examination very minute black specks are seen in the center of the Septoria spots.

Cause

The disease is caused by the fungus *Pseudopeziza ribis* Kleb. (Klebahn, 1906). The parasitic stage is known as *Glœosporium ribis* (Lib.) Mont. et Desm.

Life history

The fungus is propagated throughout the growing season by means of summer conidia which are produced in a fruiting body known as an acervulus (Fig. 78). The acervulus develops within the affected area of the host tissue, and when mature breaks through the epidermis, liberating the conidia, which are pushed out in a gelatinous mass. During a rain period the gelatinous substance is dissolved and the conidia are disseminated by wind and rain. Falling on the leaves, new infections are produced when the weather conditions are such as to afford moisture for the germination of the conidia. The conidia send out germ tubes which penetrate the leaves. Within the host tissue the germ tubes continue to develop, forming a mycelium which kills the cells, resulting in the appearance of the characteristic lesions of the disease from ten to fourteen days later.

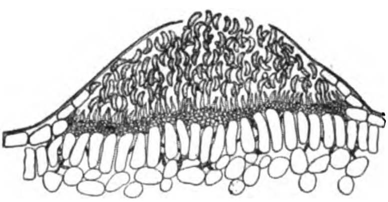


FIG. 78.— *Cross section of affected part of currant leaf, through an acervulus of the anthracnose fungus. The epidermal cells of the leaf are pushed up and the spores of the fungus are escaping*

The conidia that are produced late in the season may live throughout the dormant season and bridge the fungus over winter, but in many cases a specialized fruiting body (apothecium) is developed in the diseased leaves that fall to the ground in the autumn. In the following spring ascospores are developed in the apothecium, and usually soon after the first leaves are pushed forth on the bushes the ascospores are discharged.

(1906) Klebahn, H. Untersuchungen über einige fungi imperfecti und die zugehörigen ascomycetenformen. III. Gloeosporium ribis (Lib.) Mont. et Desm. Zeitschr. pflanzenkr. 16 : 65–83.

Carried by wind and rain they fall on the new foliage and germinate, thus producing the first infections of the season.

The fungus is apparently influenced by the same weather conditions as the other fungi causing leaf diseases. With a heavy precipitation followed by damp, cloudy weather, the disease becomes more severe. Several epiphytotics of the disease have been observed in the nursery which could be associated with a previous infection period of that nature.

Control

The suggestions of Stewart and Eustace (1901) for the control of the anthracnose disease with bordeaux mixture proved fairly satisfactory, and later Ewert (1907) found that plants sprayed with one-per-cent bordeaux mixture showed very little infection while adjacent plants were badly diseased. The applications made at intervals of from ten to fourteen days after May 1 were effective in checking the disease. Sprayings made before the first of May were of no value.

Throughout the season of 1912 an experiment for the control of the disease on Fay currants was conducted by the writer in one of the large nurseries of New York State. Three rows were sprayed with lime-sulfur 1–40, and three other rows with bordeaux mixture 5–5–50; the remaining ten rows in the block served as checks. The applications were made on the following dates: May 5 and 20, June 6 and 22, July 8, and August 4. By August 10 the unsprayed bushes were completely defoliated, while those that had been sprayed were practically free from disease and held their foliage until digging time.

A similar experiment was conducted on White Grape currant nursery stock (two-years-old bushes) in 1914, but only lime-sulfur 1–50 was used. Sprayings were made on May 8 and 21, June 5 and 30, July 25, and August 10. Frequent rains during July and August caused abundant infections and the unsprayed plants had lost their foliage by August 4. The sprayed bushes showed but little disease and held their leaves until digging time.

When applied at the proper time, bordeaux mixture 5–5–50, or lime-sulfur 1–40 or 1–50, is effective in controlling the disease. It is advisable to make the first application about the time when the leaves are unfolding, and other applications at intervals of from ten to twenty days until about five or six sprayings have been made. It is essential to keep the foliage covered and well protected throughout the summer. In a dry season so many sprayings may not be required, while on the other hand prolonged

(1901) Stewart, F. C., and Eustace, H. J. An epidemic of currant anthracnose. New York (Geneva) Agr. Exp. Sta. Bul. 199 : 63–80.
(1907) Ewert, R. Ein beitrag zur entwickelungsgeschichte sowie zur ermittelung der infektionsbedingungen und der besten bekämpfungsart von Glœosporium ribis (Lib.) Mont. et Desm. (Pseudopeziza ribis Kleb.) Zeitschr. pflanzenkr. 17 : 158–169.

wet weather necessitates more frequent applications. For the first two sprayings it is usually desirable to add 2 pounds of arsenate of lead to 50 gallons of the solution as a preventive against the attacks of worms.

SEPTORIA LEAF-SPOT OF CURRANTS AND GOOSEBERRIES

The Septoria leaf-spot (Pammel, 1891, 1892) occurs on various species of Ribes. In New York State it is often the chief cause of the dropping of currant leaves and may also be destructive on gooseberries; this is especially true for nursery stock. In the spring of 1913 this disease was exceedingly prevalent in several large nurseries that were visited by the writer, and heavy defoliation resulted during the month of June. In many cases the disease may be found on the same leaves that are affected by anthracnose.

All the standard varieties of currants and gooseberries grown in New York State may be affected, but some are more resistant than others. The white and red currants are more susceptible than the black varieties, such as Naples. It is to be noted, however, that the Septoria leaf-spot is usually more severe on the black varieties than the anthracnose disease previously discussed. Usually when affected by the leaf-spot the foliage of the white and red currants falls more readily than that of *Ribes nigrum*, variety Naples.

Symptoms

The Septoria leaf-spot disease causes rather large lesions with grayish centers and brown borders. Usually the spots are about one-eighth of an inch in diameter and are more or less angular in outline. Within the grayish center of old lesions may be observed several minute black specks (Fig. 79). The spots may be few or many on the leaf; when they are numerous, the leaf turns yellow and falls readily. The Septoria leaf-spot may be easily distinguished from the anthracnose disease (Fig. 77) by the much larger and well defined lesions, with characteristic light-colored centers. It has been reported by Stewart and Eustace (1901) that the Septoria spots on foliage of *Ribes nigrum* may be considerably smaller than the usual size found on red and white varieties, but in every case the spots are always larger than those of the anthracnose. The anthracnose lesions are black and often are no larger than a pinhead.

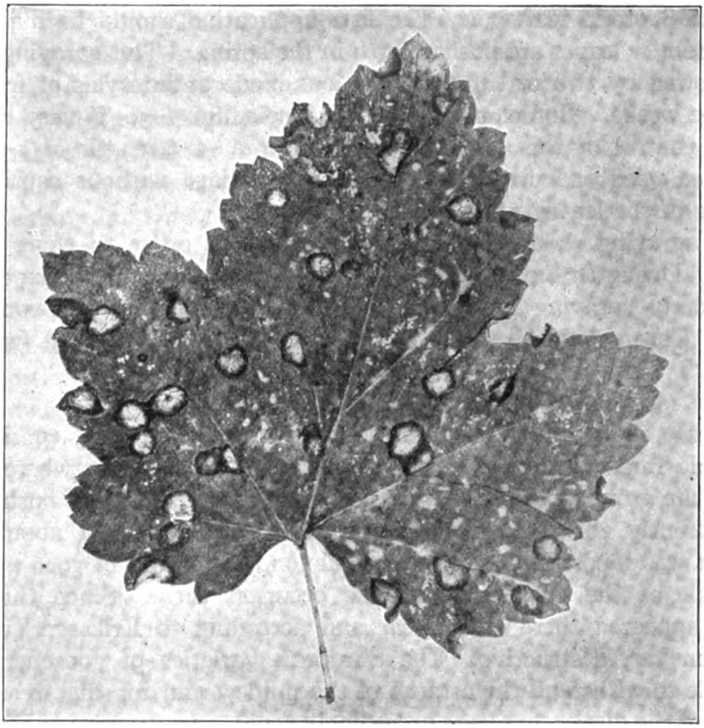
Cause

The disease is caused by the fungus *Septoria ribis* Desm., and is very similar to the fungus causing the Septoria leaf-spot of pears (Fig. 91, page 706).

(1891) Pammel, L. H. Spot diseases of currants and gooseberries. Iowa Agr. Exp. Sta. Bul. 13 : 67–70.
(1892) Pammel, L. H. Treatment of some fungus diseases. Currants. Iowa Agr. Exp. Sta. Bul. 17 : 420–421.
(1901) Stewart, F. C., and Eustace, H. J. An epidemic of currant anthracnose. New York (Geneva) Agr. Exp. Sta. Bul. 199 : 67.

Life history

When the fruiting bodies (pycnidia) of the fungus in the old spots on the leaves are mature, the spores are pushed out through the opening in the top of the pycnidium. Carried by wind and rain, they are disseminated in all directions. Falling on newly developed leaves, the spores germinate by germ tubes when moisture conditions are suitable. The germ tube penetrates the host cells and develops a mycelium within



PHOTOGRAPH BY F. C. STEWART

FIG. 79.—*A leaf of red currant affected by the leaf-spot fungus, Septoria ribis*

the leaf tissue, thus producing a new infection. The lesion becomes apparent some days later, and with the development of the fungus the spot assumes the characteristic appearance with the minute black pycnidia in the pale central dead area. Soon mature spores are pushed out of the pycnidia and a means for further spread of the fungus is afforded. The pathogen continues to spread throughout the summer whenever weather conditions are favorable. As with practically all leaf-spot fungi, heavy rains, followed by damp, cloudy weather, greatly augment the spread of this parasite.

Although not definitely determined, it is very probable that the fungus lives over winter by a sexual stage on the fallen currant and gooseberry leaves. In spring the production of spores by the sexual stage, and their dissemination to the newly developed foliage of species of Ribes, probably account for the first infections of the season.

Control

Sprayings that are suitable for the control of the anthracnose control also the Septoria leaf-spot. The first application should be made soon after the new leaves are pushed forth in the spring. This spraying should be followed by two or three applications made at intervals of from two to three weeks. Bordeaux mixture, or lime-sulfur 1–50, is very effective in the control of this disease. Lime-sulfur at a strength of 1–40 also has been used on currant and gooseberry foliage without causing any burning of the leaves.

The spraying should be thoroughly done, in order to cover all the leaves. Owing to the bushy growth, some difficulty is often experienced in properly spraying the foliage on the larger currant and gooseberry stock. Care should be taken to coat all the leaves with the fungicide.

THE GOOSEBERRY MILDEW

The gooseberry mildew is often very destructive and is of considerable economic importance. It occurs in all parts of America where gooseberries are grown and is known to occasionally affect currant bushes also.

Apparently the disease was confined to America until about 1900, when it was reported from Europe (Salmon, 1905), and in 1906 a serious outbreak of the gooseberry mildew occurred there. Since that time it has appeared there every year and according to Eriksson (1915) it has been very destructive. The European varieties of gooseberries are not able to withstand the attacks of the mildew and for that reason the spread of the disease has been exceedingly rapid. In America the varieties of gooseberries imported from Europe are more susceptible to the mildew than the varieties that have originated in this country. The Smith and Whitesmith varieties are less resistant than the Downing. The Houghton is the most susceptible of the American varieties. Although the disease is widespread there is a tendency for it to be localized in certain plantings, where it becomes established and appears to some extent each year. This condition is particularly noticeable in nursery stools, which remain on the same ground for a period of years. The mildew first appears on these stock plants and later spreads to other plantings if conditions

(1905) Salmon, E. S. On the present aspect of the epidemic of the American gooseberry-mildew in Europe. Journ. Roy. Hort. Soc. 29 : 102–110.
(1915) Eriksson, Jakob. International phytopathologic collaboration. Phytopath. 5 : 133–140.

are favorable. This disease is more destructive during wet seasons, and may flourish so abundantly that it is very difficult to control. The lower parts of the bushes, which are more or less shaded, are usually first affected.

Symptoms

The leaves, the stems, and the fruit are attacked. The first appearance of the disease is usually in May or June. Small white patches may be noticed on the fruit, usually on the lower parts of the bush where there is considerable shade. The spots on the fruit continue to enlarge, becoming somewhat darker in color, and the feltlike blotches may practically cover the fruit. If the disease is severe the fruit may be stunted in its development and may even decay somewhat.

In the nursery the mildew is commonly observed on the tips of the young shoots in June or the early part of July. The white, feltlike spots continue to enlarge and may almost completely cover the tips, extending for some distance down the shoots. If the disease is very severe the new growth is destroyed and the older wood may be considerably injured. The writer has observed second-year nursery plantings in which the foliage was almost entirely killed by the mildew during July and August. This condition not only checks the development of the stock for the season, but also makes the bushes more susceptible to winter injury.

In commercial plantings the disease is often so severe as to destroy the crop of fruit and to seriously damage the bushes.

Cause

The gooseberry mildew is caused by the parasitic fungus, *Sphærotheca mors-uvæ* (Schw.) B. & C. This fungus is very similar to the organism causing the mildew on roses (Fig. 94, page 713), and resembles in many respects the mildew of apples (Fig. 70, page 671).

Dense masses of mycelial threads of the fungus form the white patches on fruit and twigs. Certain mycelial threads are pushed up, and on these are borne large numbers of conidia.

Life history

The conidia borne in the white patches of mycelium serve to spread the fungus throughout the summer. Carried by wind and rain, a conidium falling on a gooseberry leaf germinates, if sufficient moisture is present, and produces a mycelium, which is apparent to the naked eye a few days later. With the development of the mycelium, resulting in the formation of the characteristic mildew spots, conidia are produced, which are a means of further spreading of the parasite. After midsummer specialized fruiting bodies (perithecia) are produced in the old mycelial patches of mildew on

the twigs, and these fruiting bodies, being very resistant to cold and adverse conditions, bridge the fungus over winter. In spring or early summer the perithecia discharge mature ascospores, which are carried by wind and rain and produce the first infection on the new foliage. On these infected areas conidia are developed which propagate the fungus throughout the summer.

Control

As in the case of most mildew diseases, bordeaux mixture has not proved effective in controlling the gooseberry mildew. The mycelium of this fungus is more persistent than that of most mildews, and the disease is somewhat more difficult to control. Close (1899) conducted some rather extensive experiments for the prevention of this disease, and found that potassium sulfide, 1 ounce to 2 gallons of water, was much more effective than the other mixtures tested — bordeaux mixture, lysol, and formalin. He recommends that the first spraying with potassium sulfide be made just as the buds are opening, and if the conditions are such that the disease threatens to be serious the sprayings should be continued at intervals of from ten to fourteen days.

Lime-sulfur solution 1–40 is also effective for the control of this disease. The first spraying should be made early in the season as soon as the mildew appears, and subsequent applications should be made according to the prevalence of the disease; if very abundant three or four sprayings at intervals of from eight to twelve days may be necessary in order to protect the developing shoots.

LEAF-BLOTCH OF HORSE-CHESTNUT

Leaf-blotch, also known as leaf-blight, is undoubtedly the most destructive disease affecting the horse-chestnut. This is particularly true of nursery stock. Very often the seedling beds are completely defoliated by midsummer and the growth of the young trees is greatly retarded.

When the disease has become established in a block of trees, it usually causes considerable damage each year. The affected trees develop more slowly and a longer period of time is required for them to attain a marketable size. The writer has observed certain blocks of horse-chestnuts which were so severely affected that they made practically no growth throughout the summer. Trees imported from Europe and transplanted to the nursery are sometimes not so severely injured, especially the first year. This is probably due to the fact that the trees are frequently set out at a considerable distance from other horse-chestnut plantings, and the disease does not become established in the newly planted trees the first season.

(1899) Close, C. P. Treatment for gooseberry mildew. New York (Geneva) Agr. Exp. Sta. Bul. 161 : 153–164.

The leaf-blotch disease is widely distributed and occurs in practically all countries where the horse-chestnut grows. It is very common in New York State on forest and shade trees as well as on nursery stock.

Symptoms

The leaves, and occasionally the petioles, are affected. The first indication of the disease on the leaf is a slight discoloration on the upper side, resulting in the formation of a small yellowish or red spot, about one millimeter in diameter. After three or four days, as the disease extends into the healthy tissue from the point of infection, the lesion appears water-soaked. Gradually the center of the lesion becomes dark red to brown in color, while the margin shows the yellowish discoloration, blending into the green of the healthy tissue; and finally the discolored area becomes dried out and dead. The spots are somewhat irregular in shape; they may be small or of considerable size, involving a large part of the leaf and causing the dead area to curl (Fig. 80). Clusters of minute black specks may be noticed occasionally in the diseased area.

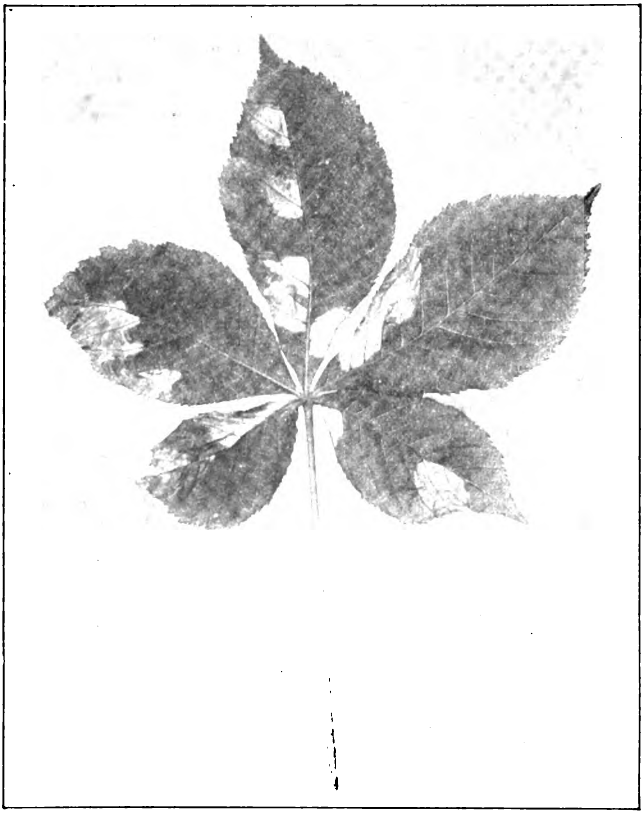


FIG. 80.— *Leaf of a horse-chestnut seedling affected with the leaf-blotch disease. Some of the leaflets are slightly curled and distorted*

The disease appears on the petioles as irregular dark brown areas. Usually the lesions extend up and down the petiole, and they may be somewhat longer than wide.

Cause

The disease is caused by the fungus *Læstadia æsculi* Peck, of which the conidial and parasitic form is known as *Phyllosticta paviæ* Desm.[2]

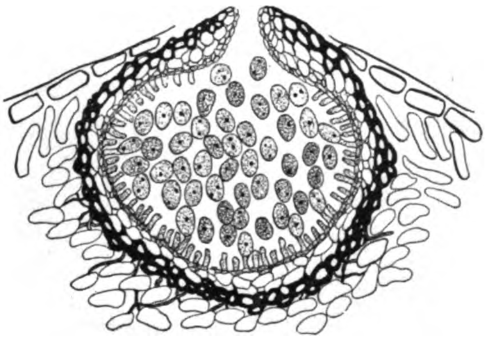


FIG. 81.— *Cross section of horse-chestnut leaf through a pycnidium of the fungus, showing the spores inside, which escape through the opening in the top of the pycnidium*

Life history

In certain areas of the older lesions, numerous fruiting bodies (pycnidia, Fig. 81) may be noticed, appearing as small black specks. When these are mature, spores are discharged from them and disseminated by wind and rain. Falling in a suitable place, such as on a horse-chestnut leaf, the spore germinates in the presence of moisture and produces a new infection, which is apparent in from about eight to twelve days. In this lesion new pycnidia are produced which discharge mature spores, and in this way the fungus continues to spread throughout the summer. The fungus lives over winter by means of the sexual stage (perithecia, Fig. 82), which develops on the fallen leaves. In early spring ascospores are discharged from the perithecia in the old leaves, and if they fall on the newly developed foliage, with conditions suitable for their germination, they produce the first infections of the season. From these infections the pycnidia are produced and the fungus is spread further throughout the summer.

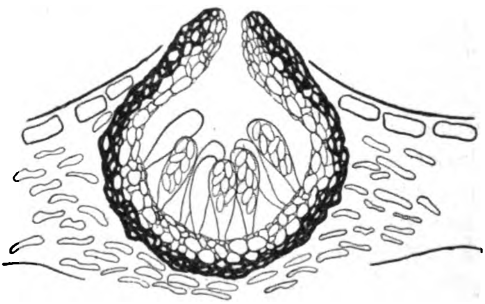


FIG. 82.— *Cross section of horse-chestnut leaf through a perithecium, showing the saclike bodies (asci) with ascospores. In early spring the spores are discharged from the asci and escape through the opening in the top of the perithecium*

[2]In May, 1885, G. W. Clinton collected this fungus near Albany on the petioles of *Æsculus hippocastanum*, and it was described by C. M. Peck (Report of New York State Botanist 39: 51. 1885) as a new species. He gave it the name *Lastadia æsculia*. In May, 1914, the writer collected fallen horse-chestnut leaves which showed a similar fungus, and a similar organism was observed also on horse-chestnut leaves which were affected with the leaf-blotch in the fall of 1913 and had been exposed to the weather throughout the winter months in a wire screen. Inoculations with ascospores, resulting in the production of the characteristic Phyllosticta lesions, show that the fungus on the over-wintered leaves is the sexual stage of *Phyllosticta paviæ*. Morphological studies led the writer to believe that the fungus named by Dr. Peck as *Læstadia æsculi* Peck and the fungus on the wintered leaves are identical. It is of interest also to note in this connection that a spermogonial stage has been observed in the life cycle of the leaf-blotch fungus. A more complete discussion of this question is to follow in a subsequent publication.

Control

But little experimental work has been done in the control of this disease. Fairchild (1894) conducted some experiments for the prevention of the leaf-blotch in the nursery and obtained fairly satisfactory results with the use of bordeaux mixture. The sprayed seedling trees made a better growth, and also held their foliage longer, than the untreated trees. Fairchild was of the opinion that better results would have been obtained if the applications of the fungicide had been more numerous. Several attempts have been made by the writer to check this disease in the nursery, but the results were not satisfactory. The disease has always been found to a large extent on the treated trees. It is believed, however, that the sprayings were not started early enough. Studies of the life history of the fungus indicate that the first infection may occur soon after the new leaves push forth. In order to prevent the fungus from becoming established, therefore, it is necessary to spray before these first infections occur in early spring.

Lime-sulfur solution 1–40, also lime-sulfur plus iron sulfate, 3 pounds to 50 gallons, and bordeaux mixture, were used in the experimental work for the control of this disease. The sprayed trees showed less disease than did the untreated stock. Commercial bordeaux mixture did not stick so well to the smooth foliage of the horse-chestnut as did the lime-sulfur solution.

It is recommended that the first spraying for the prevention of this disease be made just after the leaf buds burst in the spring. This application should be followed by at least two other sprayings, made at intervals of from ten to fourteen days. Two or three additional applications are usually advisable. The time for these later sprayings should be governed by weather conditions; in rainy seasons the applications need to be made more frequently in order to keep the foliage covered and protected.

PEACH LEAF-CURL

Peach leaf-curl is distinctly pecular to the peach and to forms derived from it, such as the nectarine and the peach almond. The peach is the natural host for the leaf-curl parasite, but the disease has been observed, though rarely, on plums and almonds also.

Leaf-curl is now a more or less common disease in all regions where peaches are grown. It has been known for a long time in England, where it was described as early as 1821, by an English gardener, as "blister." According to Pierce (1900), it is usually severest near the seacoast or large

(1894) Fairchild, D. G. Experiments with fungicides to prevent leaf-blight of nursery stock. Horse-chestnut leaf-blight (*Phyllosticta sphaeropsoidea* E. & E.) Journ. myc. 7: 352–353.
(1900) Pierce, N. B. Peach leaf curl: its nature and treatment. U.S. Agr. Dept., Veg. Path. and Phys. Div. Bul. 20: 1–204.

interior lakes. It is very common and destructive in the peach-growing section of the United States and Canada, about the Great Lakes.

Pierce (1900) has est mated that the annual loss caused by this disease in the orchards of the United States is $3,000,000. In the nursery the loss is particularly noticeable from the fact that the young trees are affected when they are in the most critical stage of their development, namely, just as the grafted buds start to grow in the spring. Peach leaf-curl was epiphytotic in the nurseries of New York State in 1909 and also in 1910. Careful observations as to the damage caused by this disease showed that about eighty-five per cent of the infected shoots failed to develop into first-class trees. The following is taken from notes made by the writer on July 16, 1910, with reference to the leaf-curl disease in one of the large nurseries of this State.

" A severe windstorm blew over many peach trees (first-year buds). In most cases the trunks of these trees were affected with the peach leaf-curl disease. Weekly measurements have been made of about two hundred and twenty trees since May 30. The average height of the healthy stock on July 8 was 34 inches, as compared with 14 inches for the average height of the diseased stock. Out of sixty-eight diseased trees ten are first-class stock, fifty can never be put on the market, and it is doubtful whether four are salable. Out of fifty-six healthy trees recorded, fifty-four are first-class stock."

Varietal susceptibility

Different varieties grown under similar conditions show marked differences in susceptibility to the disease. A comparison of data on varietal resistance of trees in different regions may show some conflicting statements as to the resistance of certain varieties. This, no doubt, is due to the fact that the same variety is known to show marked difference in its resistance to leaf-curl when grown under diverse environmental conditions (Duggar, 1899).

In 1909 and 1910, when peach leaf-curl was very abundant in the nurseries of New York State, accurate counts were obtained as to the susceptibility of the different varieties. In Table 3 are listed the different varieties, the total number of trees of each variety, and the number and percentage of trees that were so badly diseased as to be unsalable. It is to be considered that the number of trees affected greatly exceeds the number included in this table, which gives only the number of trees that were ruined. Some shoots having only one or two leaves affected outgrew the disease, and the trees developed sufficiently to be marketable.

(1899) Duggar, B. M. Peach leaf curl. New York (Cornell) Agr. Exp. Sta. Bul. 164 : 371-388.
(1900) Pierce, N. B. Peach leaf curl: its nature and treatment. U. S. Agr. Dept., Veg. Path. and Phys. Div. Bul. 20 : 1-204.

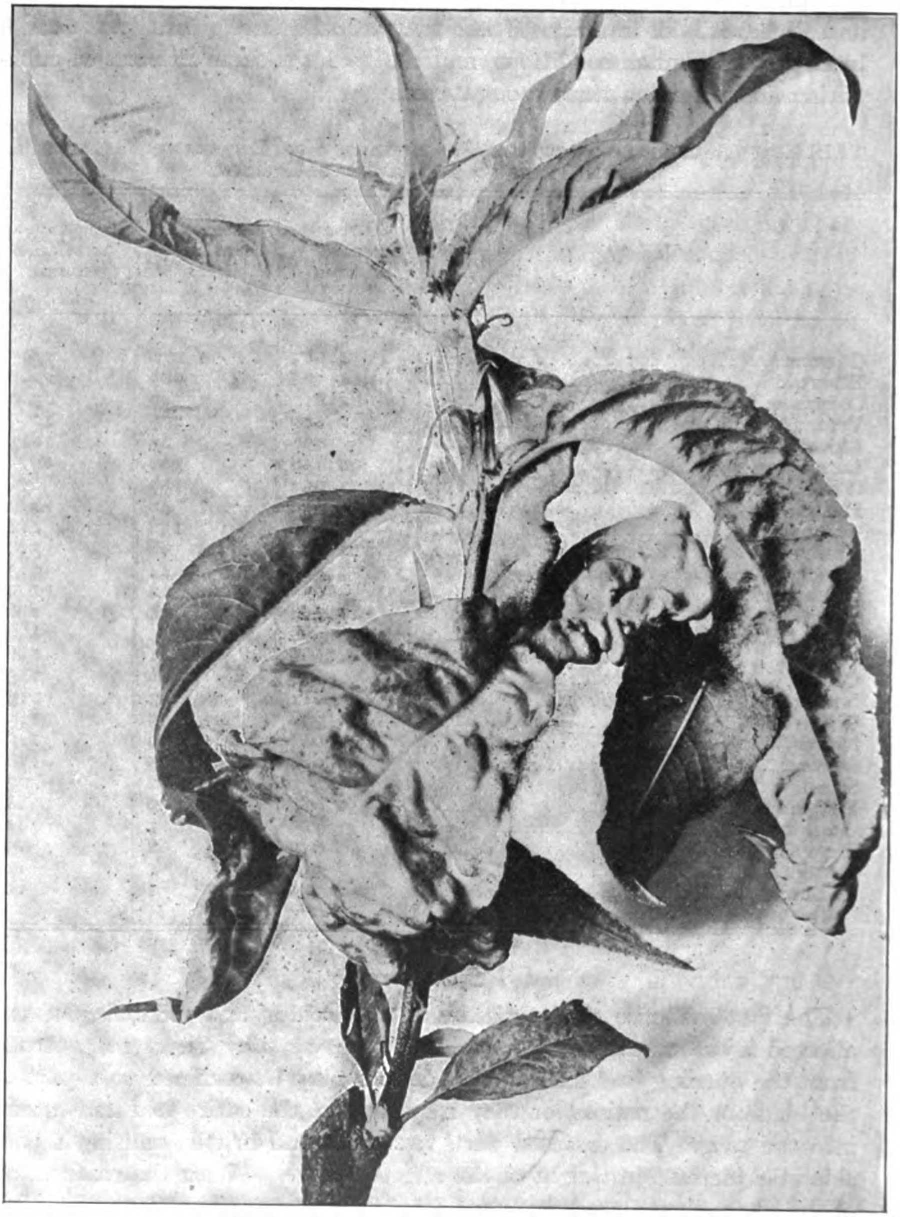
A comparison of the percentage of diseased trees of the varieties Carman and Richards is of interest. These two varieties were grown in the same block, under similar conditions, and received the same amount of cultivation and attention throughout the season.

TABLE 3. A COMPARISON OF THE SUSCEPTIBILITY OF DIFFERENT VARIETIES OF PEACH TREES TO THE LEAF-CURL DISEASE

Variety	Total number of trees	Number of unsalable trees	Percentage of unsalable trees
Carman	4,185	1,076	25.7
Elberta	4,375	903	20.6
Oldmixon Free	2,812	390	13.9
Triumph	2,120	273	12.9
Mountain Rose	431	49	11.4
Late Crawford	2,838	300	10.6
Globe	1,953	169	8.6
Heath	851	42	4.9
Champion	3,130	132	4.2
Crosby	2,279	86	3.8
Smock	1,899	44	2.3
Wheatland	636	12	1.9
Stump	1,448	24	1.6
Willet	308	5	1.6
Wager	686	11	1.6
Chairs	680	10	1.5
Niagara	681	9	1.3
Chili	378	5	1.3
Morris White	684	9	1.3
Salway	582	5	.8
Sneed	273	2	.7
Fitzgerald	2,086	9	.4
Greensboro	725	3	.4
Early Canada	639	2	.3
Foster	530	1	.19
Richards	2,398	1	.04

Symptoms

The first evidence of the disease is the arching and reddening of the affected areas in the young unfolded leaves as they begin to protrude from the opening bud scales. The lesions may be confined to a part of the blade or the petiole, or they may involve the entire leaf and extend into the twig. The diseased parts are thick and brittle, causing a considerable increase in weight of the affected leaves. With the maturation of the leaves the pale yellow or red color disappears and the hypertrophied area on the upper surface becomes silvery in appearance. The first leaves to expand are usually the most affected, and the curled leaves finally die and drop from the tree. A new crop of leaves may be developed on orchard trees following the defoliation, and these are seldom affected.



PHOTOGRAPH BY WALLACE AND WHETZEL

FIG. 83.— *A peach bud, showing the effects of the leaf-curl disease on leaves and stem*

The flowers and the young fruit of orchard trees may also be attacked, according to Wallace and Whetzel (1910), and on the rapidly growing shoots the disease causes a marked swelling, checking their growth in length and causing a marked increase in diameter.

The sickly, yellow, curled foliage and the distorted shoots of the young buds (Fig. 83) are the striking characters of this disease in the nursery. Also, the badly affected trees are considerably shorter than the healthy stock (Fig. 84).

Cause

The disease is caused by an ascomycetous fungus known as *Exoascus deformans* (Berk.) Fckl. On the surface of old affected tissues the fungus

Fig. 84.— *Carman peach buds. The trees on the left were affected with leaf-curl early in the season and made a stunted growth as compared with the healthy trees shown on the right. Photograph made on July 15, 1910*

develops minute saclike bodies, known as asci (Fig. 85). These contain spores which are discharged and serve as a means of disseminating the fungus.

Life history

The complete life history of the parasite is as yet unknown. Although not definitely determined, it is presumed that spores of some kind which propagate the fungus are lodged by wind or rain among the hairs of bud scales of the host plant in spring, and remain dormant over winter until favorable conditions arise in the following year.[3] In spring the

(1910) Wallace, Errett, and Whetzel, H. H. Peach leaf curl. New York (Cornell) Agr. Exp. Sta. Bul. 276 : 157–178.

[3] The question arises as to the use of scions cut from trees on which there is considerable leaf curl. In the year 1910, when there was a very large amount of curl in one of the large nurseries of the State, all the scions for budding were cut from blocks in which there were many affected trees. In the following year conditions were unfavorable for the disease, and only one diseased bud was observed out of the 300,000 trees examined.

spores germinate during rains, which cause the buds to swell; and the germ tube, passing in between the loosened bud scales, penetrates and establishes the parasite within the young leaf tissues. It was at one time believed that the mycelium of the fungus was perennial, wintering in the diseased twigs, growing out into the leaves, and developing shoots in the spring; but according to Pierce (1900) it is very doubtful whether infections arise in the early spring from a perennial mycelium.

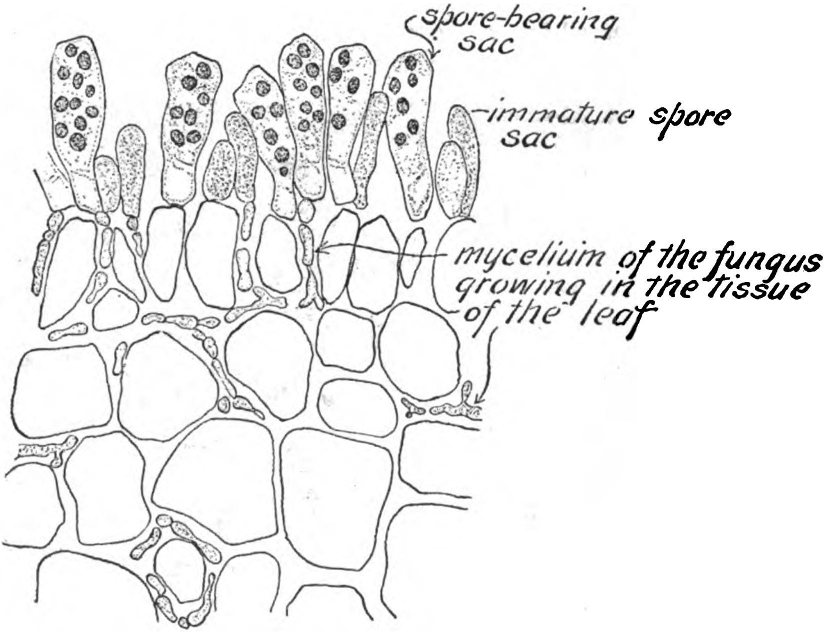


FIG. 85.— *Cross section of a diseased part of a peach leaf, showing the fungus and its relation to the leaf tissue. After Wallace and Whetzel*

Control

Bordeaux mixture or lime-sulfur 1–20 is very effective in the control of this disease. Only one spraying is necessary, but it is essential that this application be made before growth starts in the spring and the buds have started to swell. Thoroughness of the application is of absolute importance. Every bud must be completely coated with the fungicide.

For New York nurserymen, spraying each year for peach leaf-curl is considered advisable as an insurance against the disease. The spraying should be done as soon as the peach stocks are "snagged" and before

(1900) Pierce, N. B. Peach leaf-curl: its nature and treatment. U. S. Agr. Dept., Veg. Path. and Phys. Div. Bul. 20 : 1–204.

the rush of spring work begins. If it is desired to control San José scale also, an application of lime-sulfur solution 1–9 will control both the scale and the leaf-curl disease. It is absolutely essential that the grafted bud in the stock be thoroughly coated with the spray mixture. The thoroughness of the spraying depends on several factors: (1) When budding is done late some nurserymen fail to cut the strings. Many of these old strings do not rot and fall off the stocks, and in spring these may partially cover the bud, thus preventing the fungicide from completely covering the bud. (2) Plowing up to the stocks in autumn and the upheaval of the ground by frost frequently leave the bud covered with dirt at the time for spraying. (3) The most important factor is a satisfactory means of applying the fungicide. A power sprayer can be used with trailers, one man spraying each row. However, very satisfactory results have been obtained by the writer with the use of hand sprayers having an extension rod (Fig. 86). Such an outfit insures that the bud will be reached by the spray mixture and thoroughly covered. Lime-sulfur solution is preferable for leaf-curl spraying, as the application can be combined with the spraying for San José scale, which is done while the trees are still dormant.

PHOTOGRAPH BY D. GUNN

Fig. 86. — *Compressed-air hand sprayer, with extension rod and nozzle attached*

Although the natural buds on the stocks are also attacked, no damage occurs from these infections as the natural buds are sprouted soon after growth begins. In some seasons there may be considerable infection in the natural buds while the grafted bud-shoots remain free from disease. This condition is doubtless due to the fact that the natural buds start growth a few days earlier than the grafted buds. With conditions favorable for infection when the natural buds started to develop, the failure of the grafted buds to become diseased some days later can be attributed to changes in the weather, particularly a rise in temperature.

From the information at hand it may be generally stated that the peach leaf-curl disease is of considerable economic importance, both to the orchardist and to the nurseryman. It is the usual practice of the orchardist

to spray for this disease each year, and this policy should be adopted by all nurserymen who grow peach stock. The curl usually appears in epiphytotic form, causing heavy losses one year while the next year the stock may be entirely free from it. One man with a hand sprayer can thoroughly cover twenty thousand stocks in a day. The annual cost of this operation can be compared in no way with the great insurance afforded against the disease in years when the curl is destructive.

LEAF-BLIGHT OF PEAR AND QUINCE

Leaf-blight of pear and quince, sometimes called fruit-spot or scald, has been known for many years in America as well as in Europe, where it was reported in France as early as 1815. It is known to occur in practically all countries where pears are grown, and also on various other hosts. The disease is prevalent particularly in Germany, Sweden, Italy, and France. In the United States it is most common in the pear-growing sections of the Appalachian region, and the disease is well known in practically all nursery districts.

Occurrence on different hosts

In the nursery the disease is usually found in abundance on budded quince stock and pear seedlings (Duggar, 1898). It is known to occur also on Cratægus and apple,[4] and according to Southworth (1889) it has been found on *Cotoneaster tomentosa* and *Mespilus germanicus*, two plants related to the quince and the pear. All the standard varieties of quince grown in New York State nurseries are susceptible to the disease. The same may be said of the pear varieties, but the Kieffer and the Angouleme are perhaps more resistant than the Seckel and the Wilder Early. The Flemish is only occasionally attacked.

An abundant infection on both the leaves and the twigs was observed in 1913 on two-years-old trees of *Cratægus oxyacantha*, variety Paul White Thorn. Adjoining these in the same block were trees of *Cratægus oxyacantha*, variety Double White Thorn, which were practically free from disease.

Symptoms

Leaves, petioles, leaf scales, twigs, and fruit may be attacked. The disease appears first on the leaves as small discolored areas on the upper surface, which become carmine-red in the center, with dull borders, and

(1889) Southworth, Miss E. A. Leaf-blight and cracking of the pear. U. S. Agr. Dept. Rept. 1888: 357-364.
(1898) Duggar, B. M. Some important pear diseases. II. Leaf blight. New York (Cornell) Agr. Exp. Sta. Bul. 145: 611-615.

[4] The foliage of two-years-old apple trees was observed by W. H. Burkholder and the writer to be affected with Entomosporium in the summer of 1912.

which finally penetrate to the lower surface. The color soon changes from red to dark brown, and a minute, slightly elevated, black area appears in the center (Fig. 87).

The individual spots are more or less circular in outline. If the spots are very numerous, the tissue between them may be involved and the spots may coalesce. When the trees are severely attacked the leaves turn yellow or brown, especially those of quince, and readily fall. Complete defoliation of nursery stock is very common when this disease is severe.

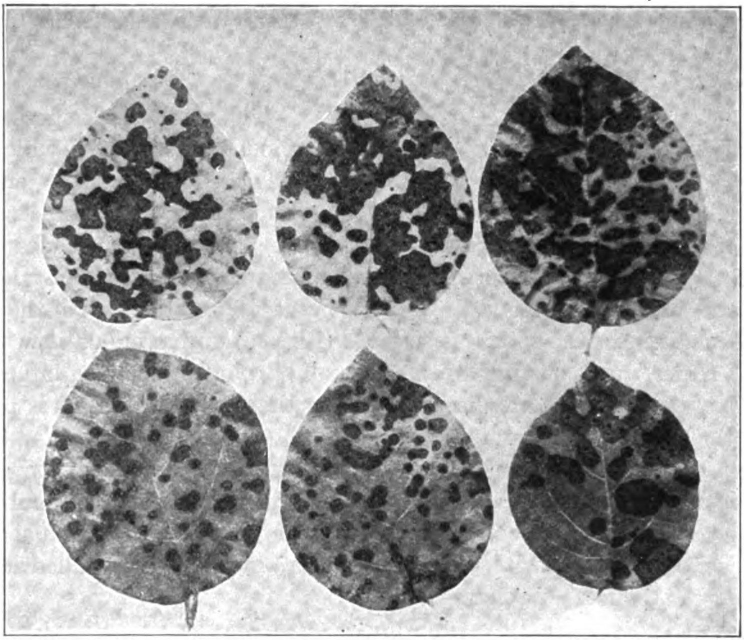


FIG. 87.—*Quince leaves affected with the leaf-blight disease, showing the dark red spots with black centers. The yellow discoloration also is apparent on some of the leaves*

Leaf-blight may be distinguished from the Septoria leaf-spot in that the spots are smaller, more colored when young, and somewhat more circular. The Septoria spots are apparent on the undersurface of the leaf. In the nursery, Septoria spot is generally found on budded pears, while leaf-blight is commoner on quinces and pear seedlings.

The development of the disease on the twigs is about the same as on the leaves. The spots are at first small and circular, but later they increase in length and become somewhat depressed, with a slight elevation in the center. The color finally changes to a brownish black. A twig

may be girdled by the disease, causing the death of the twig above the point of girdling.

Cause

The disease is caused by the fungous parasite *Fabræa maculata* Atk. The fungus is also occasionally referred to as *Stigmatea mespili* Sor., but the former appears to be the more logical name for this organism. The parasitic stage of this fungus is known as *Entomosporium maculatum* Lev.

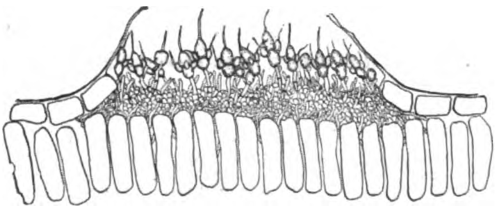


FIG. 88.— *Cross section of acervulus of fungus on quince leaf, showing the insectlike spores. The cuticle and the epidermal cells of the leaf have been pushed up and broken*

Life history

The small black specks previously mentioned, which develop in the center of the affected areas of the leaf, are the reproductive bodies (acervuli) of the fungus. Within the acervulus (Fig. 88) spores are developed, which on being discharged are carried by wind and rain to the foliage. Under favorable conditions, with the presence of moisture, the spores germinate (Fig. 89) and produce new infections. After three or four weeks acervuli develop in the new infections, and from these spores are discharged. In this way the fungus is propagated throughout the summer.

Some of the spores may live over winter on the diseased twigs and produce new infections when growth starts in spring; but no doubt the greater proportion of infections in early spring is due to the sexual stage (perithecia) of the parasite. The perithecia develop on the fallen leaves, and the next spring discharge many spores which are carried by wind and rain to quince and pear foliage; the spores germinate with the presence of moisture, and produce the first infections of the season.

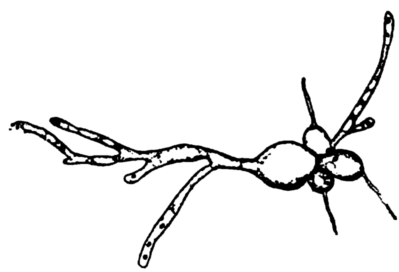


FIG. 89.— *An Entomosporium spore which has germinated. Germ tubes have developed from two cells of the spore. Highly magnified*

Cross inoculations

Cratægus on pear and quince.— Abundant leaf, petiole, and twig infection of *Entomosporium maculatum* was observed on June 13, 1913, on two-years-old trees of *Cratægus oxyacantha*, variety Paul White Thorn. Spores from acervuli on the leaves were placed in water. By means of an atomizer two pear seedlings and two

quince seedlings were sprayed with the suspension of spores. Two pear seedlings were sprayed with sterile water for checks. The seedlings were then placed in moist chambers for three days. Seven days later infections were apparent on all the inoculated seedlings; mature fruiting bodies developed on the inoculated leaves within twenty to twenty-five days after inoculation. The check trees remained healthy.

Pear on quince and Cratægus.— On June 23, 1913, two quince seedlings and two Cratægus shoots were inoculated, in the manner described above, with Entomosporium spores from diseased pear leaves. Two quince seedlings were sprayed with water free from spores as checks. Infections on both quince and Cratægus were found after ten days. Mature fruiting bodies developed after twenty-four days. The check trees remained healthy.

Quince on pear.— On June 28 Entomosporium spores from affected leaves from two-years-old budded quince trees were used for the inoculation of three pear seedlings. Inoculations were made as described above. Two pear seedlings were used as checks and were sprayed with water free from spores All the inoculated trees were placed in moist chambers for three days. Infections were apparent on the inoculated trees nine days later; mature acervuli developed in twenty to thirty days after inoculation. The check trees remained healthy.

From these cross-inoculation experiments it is to be concluded that there are no physiological differences in the fungus on the various hosts. The same organism will attack pear, quince, and Cratægus.

Control

Bordeaux mixture of any standard strength has been shown to be effective for the control of this disease. Galloway's (1889, 1894) and also Fairchild's (1893-4) experiments on this disease in the nursery proved spraying to be profitable. Sprayed pear seedlings held their foliage much better than did unsprayed trees, and were also somewhat larger.

Experiments by the writer on the control of this fungus in the nursery have shown both bordeaux mixture and lime-sulfur solution to be effective. Lime-sulfur solution 1–50 is satisfactory as a preventive. It has been the experience of the writer that, as a rule, the spraying of pear buds and quince seedlings for leaf-blight is not necessary in the nursery. For budded quince stock, the first spraying should be made soon after the first leaves are developed, when the young buds are from eight to twelve

(1889) Galloway, B. T. Experiments in the treatment of pear leaf-blight and the apple powdery mildew. U. S. Agr. Dept., Veg. Path. Sec. Circ. 8 : 1–11.
(1893-4) Fairchild, D. G. Experiments in preventing leaf diseases of nursery stock in western New York. Pear leaf-blight. Journ. myc. 7 : 241–247, 338–351.
(1894) Galloway, B. T. The effect of spraying with fungicides on the growth of nursery stock. U. S. Agr. Dept., Veg. Path. Div. Bul. 7 : 1–41.

inches in height. Subsequent sprayings should follow at intervals of from ten to fourteen days until about five applications have been made. For a rainy season it may be necessary to make one or two extra applications, it being essential to keep the new leaves covered with the fungicide.

The foliage of newly planted seedlings does not develop as early as stock that has remained in the ground over winter, and therefore the first spraying for leaf-blight on pear stocks can be delayed somewhat. It is advisable, however, to make the first application soon after the first leaves are developed. Four or five sprayings throughout the summer are sufficient to keep the disease in check. When extreme dry weather prevails throughout early summer and midsummer, the intervals between the first sprayings may be extended somewhat. If the applications are made at intervals of three weeks or less, a greater proportion of the foliage is protected at all times.

The addition of 3 pounds of iron sulfate to lime-sulfur solution 1–50 greatly increases the sticking qualities of the mixture on pear foliage.

SEPTORIA LEAF-SPOT OF THE PEAR

Leaf-spot of pear is common in all the nursery districts of New York State and is widely distributed throughout the United States in both orchards and nurseries. It is known to occur in Europe also.

The disease is confined to the foliage, and in the nursery the budded stock is the most susceptible. Duggar (1909) observed that, while seedling pear stock in a nursery may show leaf-blight to a considerable extent, adjacent plats of budded plants may be seriously injured by leaf-spot. The budded stock of the second year usually suffers seriously. Sorauer (1908) states that the disease is occasionally found on apples.

When leaf-spot is abundant, considerable premature defoliation results and the growth of the stock is checked. As a rule, however, the disease is not so destructive as the pear leaf-blight so commonly found on pear seedlings.

Certain varieties of pears are more susceptible to the disease than others (Duggar, 1898). In the nurseries of New York State, observations throughout several seasons show the following varietal differences in resistance to the leaf-spot: most severely attacked, Sheldon, Seckel, Bartlett, Wilder Early; considerably injured, Worden, Anjou, Howell, Vermont Beauty, Flemish, Koonce, Clapp Favorite, Clairgeau; most resistant, Kieffer, Garber, Mount Vernon, Lawrence, Angouleme.

(1898) Duggar, B. M. Some important pear diseases. I. Leaf spot. New York (Cornell) Agr. Exp. Sta. Bul. 145 : 597–611.
(1908) Sorauer, Paul. Septoria piricola. Handbuch der Pflanzenkrankheiten 2 : 408.
(1909) Duggar, B. M. Fungous disease of plants, p. 358–360.

Symptoms

Only the leaves are affected. The lesions appear first on the upper surface as discolored spots, which are rather characteristic and make the disease easily recognized. Usually the spots are not abundant on a leaf unless the disease is exceptionally common; under this condition some of the lesions may coalesce, involving the healthy tissue between. The affected area is somewhat angular in shape; the outer part of the spot is brown or black in color, while the well-differentiated center is light

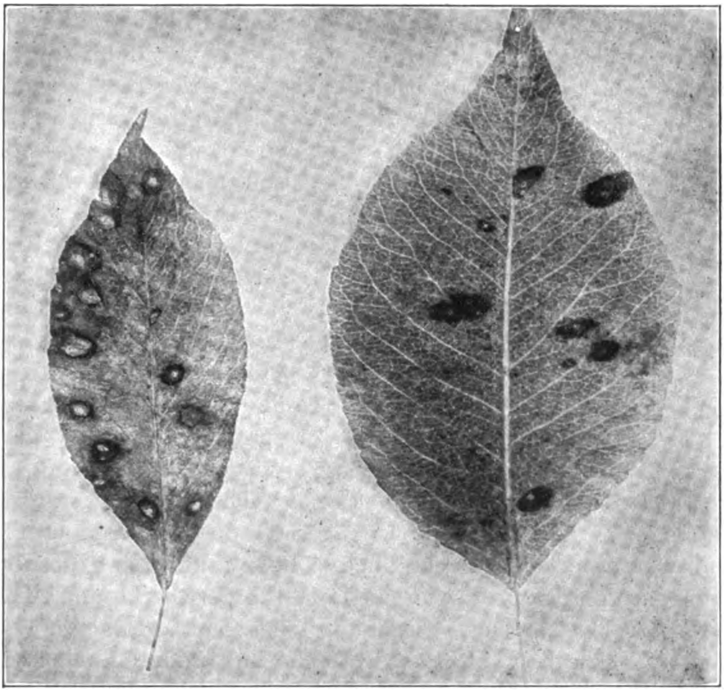


FIG. 90.— *Pear leaves affected with the Septoria leaf-spot disease. Some of the spots show the dark specks (pycnidia) in the center of the white areas*

gray, with six to twelve minute black specks which are very apparent in old leaves. The spots measure, on an average, one and one-half to two millimeters, and the grayish center is somewhat transparent (Fig. 90).

The leaf-spot disease can be distinguished readily from the leaf-blight by the larger angular lesions, which show through more distinctly on the undersurface. The gray center of the leaf-spot lesion is also characteristic. The leaf-blight areas are more highly colored when young, and are circular, not angular, in outline.

Cause

The disease is caused by the fungus *Mycosphærella sentina* (Fckl.) Schröter. The conidial stage, *Septoria piricola* Desm., is the parasitic form of the fungus, and it is this stage that attacks the living pear leaves throughout the growing season. Klebahn (1908) showed that *Mycosphærella sentina* on old wintered-over pear leaves is the sexual stage of *Septoria piricola*.

Life history

The minute black specks, previously mentioned as occurring in the center of the spots on the leaf, are the pycnidial fruiting bodies. Spores are pushed out of the opening at the tip of the pycnidium (Fig. 91) in the form of a dark-colored, tendril-like mass. Carried by the wind or by a spattering drop of rain, a spore falls on a pear leaf and, if sufficient moisture is present, germinates. The germ tube penetrates the leaf tissue and develops a mycelium, and the new infection is established. In this lesion new pycnidia are produced which bear spores, and thus the pathogen is spread throughout the summer.

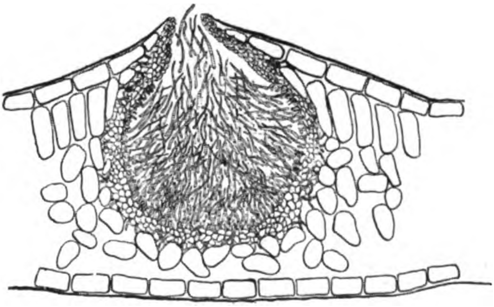


FIG. 91.— *Cross section of pear leaf, showing a pycnidium of the Septoria fungus and the needlelike spores, some of which are escaping through the opening in the top of the pycnidium*

The fungus lives over winter on the fallen pear leaves in the form of a specialized reproductive body known as a perithecium. In spring ascospores are discharged from the perithecia, and, falling on the newly developed foliage, germinate when moisture is supplied. In the lesions of these first infections pycnidia are produced, which are the means of further dissemination of the fungus.

Control

The leaf-spot of pear can be controlled by spraying with bordeaux mixture or with lime-sulfur solution 1–50. It is advisable to spray the two-years-old budded pear trees soon after the first new leaves are developed in spring. This spraying should be followed by another application two to three weeks later. If the season is extremely wet and the disease very common, one or two subsequent sprayings will prove beneficial.

(1908) Klebahn, H. Untersuchungen über einige fungi imperfecti und die zugehörigen ascomycetenformen. V. Septoria piricola Desm. Zeitschr. pflanzenkr. 18 : 5–17.

It has been the experience of the writer that in an average year it is usually not profitable to spray one-year-old budded pear stock for this disease. During the several years that the disease has been under observation in the nurseries of New York State, the writer has never noticed leaf-spot causing any heavy defoliation of one-year-old trees.

BLACK SPOT OF ROSES

The disease known as black spot, leaf-blotch, or leaf-spot is one of the most destructive diseases occurring on roses. The disease has been known for nearly a century, and is found in practically all the countries of Europe as well as being widely distributed in the United States (Scribner, 1888). In nurseries the plants that are severely affected become defoliated during the summer, in many cases causing the leaf buds, which should remain dormant until the following year, to open late in the season. The defoliation checks the growth and also prevents proper maturation of the wood, and when dug the stock is not likely to keep so well in storage. In the following spring, when these bushes are put on the market, they go out as weakened plants so that they blossom poorly or not at all. Stock that makes a good growth and is productive the first year it is set out is most desired by the nurserymen's trade.

The disease is also destructive in the greenhouse, especially where cuttings are propagated and later planted in the nursery row. The small plants in pots are often badly injured, a large proportion of the foliage being affected. When these potted roses are transplanted to the field, the weakened condition of the foliage retards the development of the plants and in some cases they die, especially if the season is dry.

Varietal susceptibility

Practically all varieties of roses are affected, both in the nursery row and in the greenhouse. The wild species, *Rosa humilis*, has been reported by Halsted (1893) as being attacked when growing in the garden near diseased roses. Certain forms are known to be resistant. Wolf (1913) makes the following statement:

"*Rosa gallica*, *R. centrifolia*, *R. rubiginosa*, and *R. indica* exhibit a marked degree of resistance. Some forms are entirely free from attack. Briosi and Cavara note that only four varieties, *Rosa hybrida*, varieties Bell Angevine, Triomphe d'Alencon, Abel Grant, and *Rosa borboniaria*, variety Triomphe d'Anger, of the six hundred growing in the botanical gardens at Pavia are free from attack. Laubert and Schwartz point out

(1888) Scribner, F. L. Black-spot on rose leaves. U. S. Agr. Dept. Rept. 1887 : 366–368.
(1893) Halsted, B. D. Fungous troubles of roses. New Jersey Agr. Exp. Sta. Rept. 13 : 280–281.
(1913) Wolf, F. A. Black spot of roses. Alabama Agr. Exp. Sta. Bul. 172 : 113–119.

the fact that the bushy sorts are more susceptible than the climbing varieties, and also that those with thin leaves are most liable to attack."

Symptoms

The symptoms of the disease are the black, sootlike blotches on the upper surface of the leaves (Fig. 92). The more or less circular spots are at first small, but they increase in size to a half inch in diameter. Often a number of the spots coalesce, and in time the leaf may be nearly covered with the large dark areas. A very marked character is the fringed border of the spots. The affected areas of the leaf turn yellow, and this yellowing may involve the entire leaf before it falls to the ground.

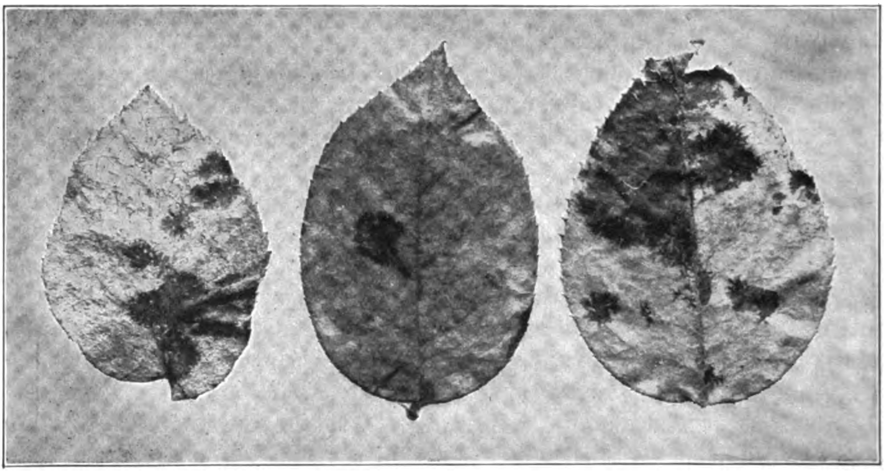


FIG. 92.— *Rose leaves showing the black-spot disease*

Cause

The cause of the disease, as determined by Wolf (1912), is the fungus *Diplocarpon rosæ* Wolf. The conidial, or vegetative, stage, which is the active parasite on the living foliage, is known as *Actinonema rosæ* (Lib.) Fr.

Life history

The disease usually first appears in the nursery in early summer, about the time when other leaf-spots are developing. In the affected areas on the leaf, fruiting bodies (acervuli) are developed, and these discharge spores which are carried by wind and rain to healthy rose leaves. In the presence of moisture the spores that fall on the leaves germinate and

(1912) Wolf, F. A. The perfect stage of Actinonema rosae. Bot. gaz. 54 : 218–234.

produce new infections. It is in this manner that the fungus is spread throughout the summer.

The fungus lives over winter in the fallen leaves. The reproductive fruiting bodies which are developed in these old leaves mature in spring, and ascospores are discharged which are carried by wind and rain to the new foliage, where the first infections of the season occur. In the presence of moisture, these ascospores germinate by a germ tube, and within eighteen days after infection the acervuli, with mature spores, have developed.

Control

Bordeaux mixture may be used for the control of this disease. No experimental data are at hand as to the efficiency of lime-sulfur solution as a preventive. Lime-sulfur solution 1–50 has been used for the control of rose mildew, with no resulting injury to the plants. No doubt this solution would be efficient also in checking the black spot disease if applied at the proper time.

Bordeaux, and also lime-sulfur, are objectionable in many cases because of the spray mixtures coating the foliage and the blossoms. The presence of the fungicide on the bushes, however, is of no consideration to nurserymen, and for that reason bordeaux mixture may be recommended for use against this disease.

The first application should be made in early summer, soon after the first new leaves are developed. In rainy seasons the disease is naturally more severe and the sprayings need to be made more frequently. However, as a general recommendation, five or six applications throughout the summer should be sufficient to keep the fungus in check.

MILDEW OF ROSE AND PEACH

Mildew is found on both the peach and the rose, but it is commoner on the latter. The disease is more destructive on peach nursery stock than on orchard trees, according to Whipple (1906); however, in the nursery it is usually prevalent only when there is an excessive amount of moisture and conditions are favorable for the disease. It has been the experience of the writer that, as a rule, peach mildew is not of sufficient economic importance to demand much attention in the nurseries of New York State.

Rose mildew is of great significance in the nurseries of the State and is in many cases very destructive. This is especially true of the young plants growing on their own roots. If weather conditions are favorable to the disease, potted roses may often be affected seriously when they are transplanted to the field from the greenhouse in spring. Certain varieties

(1906) Whipple, O. B. Peach mildew. Colorado Agr. Exp. Sta. Bul. 107 : 1–7.

of potted roses may be injured so severely by the mildew that they make but little growth throughout the summer.. In many cases stock checked in this way during the vital period of its development fails to make sufficient growth in the second summer in the field to be dug that season. This condition is more prevalent when the plants are affected by mildew and other leaf diseases again in the second year. Budded roses also are susceptible to mildew, and very often their growth is checked by the disease.

Some growers are of the opinion that severely mildewed rose stock does not keep well in storage. It is claimed that the tips of the affected shoots tend to rot and decay when subjected to the moist condition of the cellar. No experimental data are at hand to substantiate this opinion, but under ordinary conditions it is probable that the mildew disease which has affected the bushes in the summer has little or no direct influence on stock while it remains in the cellar. The mildew dies in the autumn and does not continue to spread throughout the winter. It is known that mildew kills back the tips of the shoots, but such injuries, in the writer's opinion, would be comparable to any mechanical injury that might kill the tip of a shoot. This disease is often very destructive to rose cuttings and also to stock plants in the greenhouse, according to Schultheis (1899).

Varietal susceptibility

Certain varieties of roses show more resistance to mildew than do others. The rambler varieties and the moss roses are usually the most severely affected. A serious outbreak of rose mildew occurred in one of the large nurseries in the season of 1913. There were about forty-five varieties of roses growing in one block under the same conditions, and thus a good opportunity was afforded for observations on the resistance of these varieties to mildew.

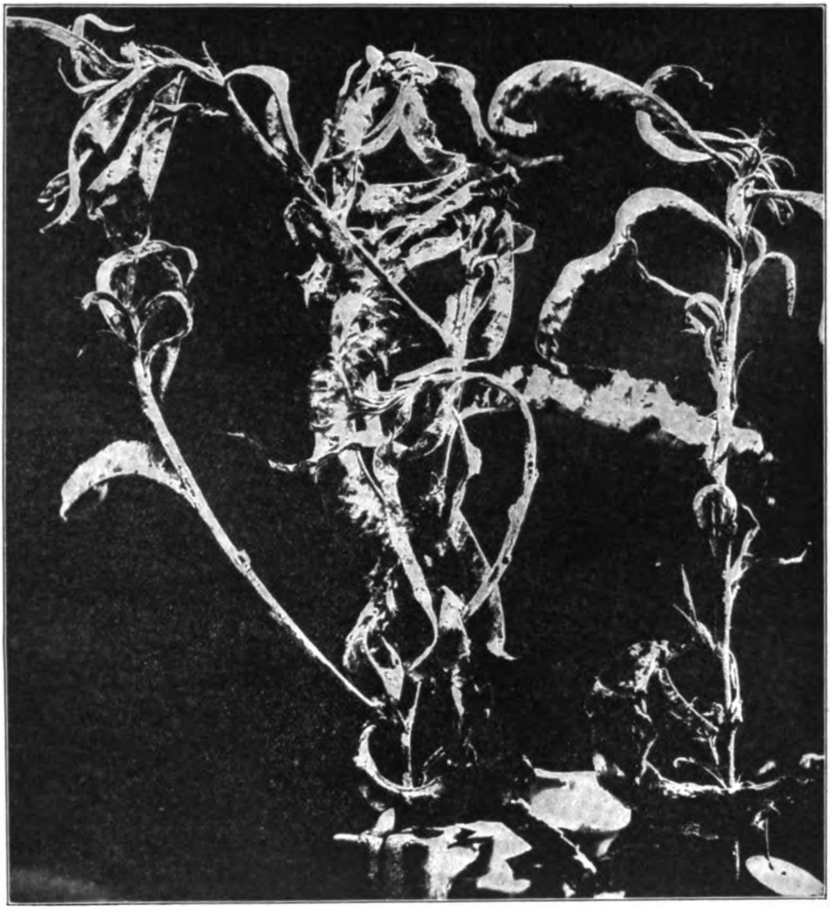
The varieties most severely affected were: Flower of Fairfield, Crimson Rambler, Anna Mueller, Margaret Dickson, Salet Moss, Blanche Roberts, and Frau Karl Druschki. The varieties showing practically no mildew when the last observations were made, on August 10, 1913, were: Dorothy Perkins, Orleans, Mrs. Taft, Princess Adelaide, Caroline Mariner, and American Beauty. All the following varieties were at least slightly affected by the disease: Victor Verdier, Mary Washington, General Washington, Madame Caroline Testout, Baby Rambler, Wichuriana, Fisher Holmes, Gruss an Teplitz, Earl of Dufferin, Lady Gay, Queen Prairie, Madame Margotten, Madame Plantier, Francois Levet, Catherine Zeinner, William Lobb, Duke of Edinburgh, Madame

(1899) Schultheis, A. Mehltau an rosen. Zeitschr. pflanzenkr. 9 : 128.

Gab. Luizit, Empress of China, John Hopper, Magna Charta, Clemence Raoux, Clio, Marshall P. Wilder, John Keynes, C. F. Meyers, Devoniensis.

Symptoms

The leaves, especially the young ones, the blossom buds, and the young shoots of roses are affected by mildew. The disease occurs on



PHOTOGRAPH BY B. M. DUGGAR

FIG. 93.— *Peach shoots severely mildewed*

the leaves, the twigs (Fig. 93), and also the fruit of the peach. The symptoms on the two host plants are practically the same.

On the leaves of the rose the disease may occur on either the under or the upper surface, or on both. It appears as white, irregular blotches. The leaves become arched or curled and dried out, usually curling upward

along the midrib. When the disease is severe the younger leaves at the end of the shoots often fall prematurely.

The dense, white blotches on the twigs caused by the mildew are similar to those on the leaves. The bark becomes dead in appearance on severely affected shoots, and shrivels, causing an arching or a curving of the shoots at the tip. Only the current year's growth is affected. Often mildew covers the foliage at the tips of the shoots so completely that certain varieties of rosebushes appear at a distance to be almost white. This is often particularly noticeable in a block of roses containing numerous varieties. Such roses as the Crimson Rambler may have the white appearance due to the mildew, while in adjoining rows the foliage of another variety will be green and free from mildew.

On some varieties the mildew is commonly first observed on the blossom buds, where it appears as thick, white, irregular blotches.

Cause

The fungus *Sphærotheca pannosa* (Wallr.) Lév. is the cause of the mildew on peach and rose stock. The conidial form is *Oidium leucoconium* Desm. This fungus is similar to the organism causing mildew on apple (Fig. 70, page 671).

Life history

Soon after the white blotches of mildew appear on the host plant, profuse numbers of conidia are produced (Fig. 94) which are scattered to the new foliage by wind and rains. These conidia propagate the fungus throughout the season. After midsummer the special fruiting bodies known as perithecia may also be produced, which are resistant to cold and serve to bridge the fungus over winter. In spring or early summer, ascospores are discharged from the perithecial fruiting body, and, falling on the new foliage, produce infections which are apparent some days later as small, white areas, the beginning of the thick, white blotches of mildew.

Control

Most copper sprays have not proved effective in controlling this disease, but compounds containing sulfur have been effective. Dusting with flowers of sulfur, spraying with lime-sulfur solution, and spraying with lime-sulfur to which iron sulfate has been added, have been tried in the nursery with a considerable degree of success.

For a normal year perhaps the simplest means of control for this disease is dusting with flowers of sulfur. The sulfur can be easily and rapidly applied with a dusting machine which blows out the sulfur in a fine dust. It is often desirable to dust as early as possible in the morning,

while the dew is still on the foliage. If dry, hot weather follows the dusting, the efficiency of the sulfur against the mildew appears to be increased. Rain washes off a certain amount of the sulfur dust, but a considerable amount remains unless there is a prolonged period of wet weather. With frequent heavy rains when the mildew is well established and abundant, the dustings need be made at shorter intervals in order to keep the new growth protected.

Lime-sulfur solution 1–50 is effective in checking mildew, but better results have been obtained by the use of lime-sulfur solution 1–50 with

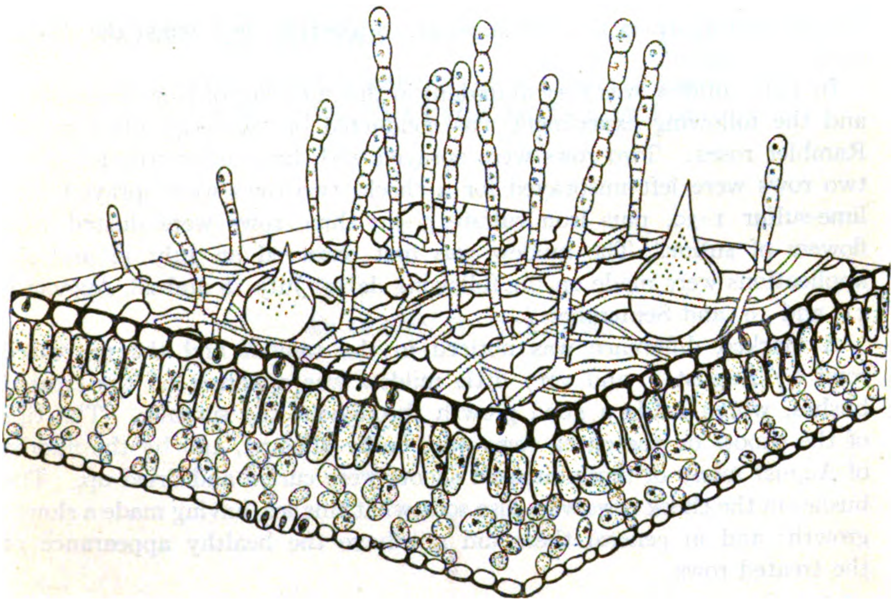


FIG. 94.— *Diagrammatic section of a piece of leaf tissue, showing the mildew fungus on the surface, with conidiophores and chains of spores reaching into the air and haustoria extending into the epidermal cells of the leaf. Magnification 150. After F. M. Blodgett*

the addition of 3 pounds of iron sulfate to 50 gallons of the mixture. The precipitated sulfur resulting from the addition of the iron sulfate appears to have better covering qualities and also sticks better.

The first treatment for mildew should be made as soon as the disease appears and before it has become thoroughly established. The abundance or prevalence of the disease should determine the time interval and the number of applications for effective control. In some seasons one or two applications are sufficient, while in other seasons it is profitable to increase the number of applications to five or six, making some of these

at intervals of nine days or oftener. Under such conditions it is often preferable to dust rather than to spray, owing to the ease and rapidity with which the former may be done. Foliage sprayed with the precipitated sulfur is, as a rule, protected more effectively for a greater length of time; but often there is need of frequent sprayings in order to protect the young developing shoots and leaves where the attacks of the mildew are most severe.

Owing to the fact that spraying involves considerable time and labor, one or two sprayings with the precipitated sulfur, in order to keep the older foliage protected, can be combined with dusting; the dust applications being made at intervals of from seven to fourteen days when the disease is most prevalent.

In 1911 mildew was very abundant in the nurseries of New York State, and the following experiment was conducted on two-years-old Crimson Rambler roses: Two rows were sprayed with lime-sulfur solution 1–50; two rows were left unsprayed for a check; two rows were sprayed with lime-sulfur 1–50, plus iron sulfate 3–50; three rows were dusted with flowers of sulfur. The mildew was first observed on July 12 and the applications were made on the following dates: July 18 and 28, August 4, 11, and 19, and September 1.

A marked difference was noticed in the treated and the untreated rows by August 4, and very little mildew was apparent on the treated bushes, which made a good growth throughout the summer. The tips of the shoots on the check rows were badly affected, and by the middle of August many of these diseased shoots were curled and dried up. The bushes in the check rows were also somewhat smaller, having made a slower growth; and in general these did not have the healthy appearance of the treated rows.

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THE COLLEGE OF AGRICULTURE

Department of Entomology

SOME EXTERNAL PARASITES OF POULTRY

WITH SPECIAL REFERENCE TO MALLOPHAGA, WITH DIRECTIONS FOR THEIR CONTROL

BY GLENN W. HERRICK

ITHACA, NEW YORK
PUBLISHED BY THE UNIVERSITY

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CONTENTS

SOME EXTERNAL PARASITES OF POULTRY

WITH SPECIAL REFERENCE TO MALLOPHAGA, WITH DIRECTIONS FOR THEIR CONTROL

GLENN W. HERRICK

Domestic fowls constitute one of the most important sources of food supply in America. In 1911 the value of poultry in the United States reached a total of $154,663,220, and the value of the eggs produced in the same year in New York State alone amounted to $17,102,000. It is thus evident that poultry occupies an important place in the living economies of the American people, and any pests that affect domestic fowls injuriously should be carefully considered. The study of the external parasites of domestic fowls has extended over several years but with many interruptions and delays. It has been difficult to collect the various species infesting fowls, and even as yet it has not been possible to obtain all the species that the writer feels must exist in the United States.

Among the external parasites of domestic fowls the Mallophaga, or lice, hold the greatest interest for the writer. Some of the most interesting questions of development, variation, and relation to environment arise out of a consideration of the geographical and host distribution of these parasites — questions too technical, however, to be discussed here.

THE MALLOPHAGA, OR BIRD LICE

STRUCTURE

The bird lice are wingless, parasitic insects of world-wide distribution. The mouth parts, formed for biting and situated on the under, or ventral, side of the head, are composed of two large, strong mandibles more or less triangular in shape. Each bears one sharp-pointed tooth, and sometimes one or two shorter teeth. The maxillæ are greatly reduced and may probably be considered vestigial. They are very little chitinized and are reduced to mere membranous lobes lying nearly concealed in the cavity of the mouth. The labrum is usually well developed and serves as an organ of prehension. The labium is present but varies in form and structure. In one suborder, the Amblycera, four-segmented palpi are borne by the labium; in the other suborder, the Ischnocera, there are no palpi. There seem to be no structures in the mouth of a bird louse that could be considered as forming a sucking apparatus. The conclusion that bird lice are biting insects and do not live by sucking the blood of the host is therefore justified.

The head is comparatively large and may be variously shaped. In many species it is concave on the posterior margin and sits on the prothorax like a hat (Fig. 97, page 728). The antennæ are always short and inconspicuous and often differ in the two sexes (Fig. 98, page 729). They are three-, four-, or five-segmented and differ greatly in shape. The eyes are simple, two in number, and neutral in color or highly pigmented. The legs of the bird lice that infest fowls are usually stout and conspicuous and terminate in two sharp claws. (The legs of the species of Mallophaga infesting mammals, with a few exceptions, terminate in a single claw.) The forelegs are short, and act as foot-jaws for passing food into the mouth.

The bird lice are permanent parasites spending their entire lives on the bodies of their hosts, the birds. They of course migrate from one host to another when the hosts are in actual contact, as when in copulation, when brooding over the offspring, or when huddling together on perches. Moreover, opportunities certainly occur for the lice of one host to actually migrate to a host of another species. For example, a certain species of louse which is normally a parasite of the hen is sometimes found on the turkey, especially where the two species of fowls are in the same yard. Two species of hen lice have been found also on guinea fowls where the latter were allowed to frequent the perches and the houses of the hens.

HOW BIRD LICE INJURE FOWLS

Bird lice have biting mouth parts and do not suck the blood of their hosts. It is doubtful whether any of the Mallophaga parasitic on domestic fowls ever get any blood except in case of a wound or a bruise on the host from which blood may issue; in such cases the parasites may eat the dried scales of blood. Blood has been found in the stomachs of bird lice, probably obtained in this manner. Kellogg[1] notes a species of bird louse that lives inside the pouch of the California brown pelican and clings to the walls of the pouch by its mandibles. Moreover, he has found a small area surrounding the parasites to be raw and bloody. It is a question in this case as to what these particular lice eat for food.

It is generally conceded that the Mallophaga live on bits of feathers and scales of the skin. Theobald speaks of them as constantly biting at the skin and causing serious irritation. Other writers hold that the constant movements of the lice cause irritation to the skin by the sharp claws with which the feet of all these parasites are furnished. The presence of the lice sets up an irritation which eventually weakens the host and gives an opportunity for various diseases to attack the fowl. This

[1] Kellogg, V. L. North American Mallophaga, p. 47. 1896.

seems to be especially true of chicks; if lice are abundant, the growth of the chicks is greatly checked, diarrhea seems to follow, and a generally weakened condition may result.

The losses caused by poultry lice are difficult to estimate, but the total must be large. When badly infested, chickens fail to make anything like their normal growth. Theobald[2] gives results showing that at the end of a year chicks infested with lice weighed one pound less than those that had been kept free from these pests, both having had exactly the same food and otherwise the same care. The loss in egg production through the infestation of laying hens must be very great, although there is no way of getting even an approximation of it. Brood hens are often so irritated by these parasites that many of the failures in hatching must be attributed to their presence. Undoubtedly the presence of lice, by weakening the general constitution of the host, predisposes the fowl to such diseases as gapes, cholera, roup, and similar affections, thus contributing to a considerable indirect loss and injury.

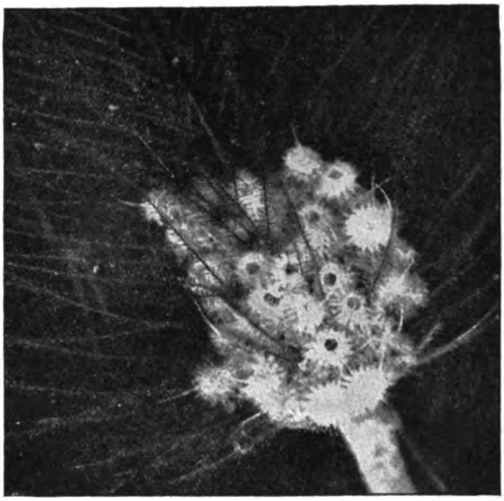

FIG. 95.— *Eggs of Menopon pallidum*

LIFE HISTORY OF BIRD LICE

The writer has made no attempt to work out the life history of any species of bird lice. The obstacles have seemed too great, and the time and effort required too extended, to justify the end. It is possible that a study of the life history of these parasites might throw some light on methods of control, but it does not seem probable.

Bird lice have an incomplete metamorphosis. The eggs are elongate-oval, white in color (all those observed), and covered with spinelike projections. The eggs of the common hen louse (*Menopon pallidum*) are usually deposited in clusters (Fig. 95) at the bases of the feathers. These clusters of eggs can usually be found, on badly infested fowls at least, on the feathers about the vent. When magnified, a single egg is seen to be a very characteristic and striking object. It is white and is covered with glasslike spines, many of which terminate in an anchor-

[2] Theobald, F. V. The parasitic diseases of poultry. 1896.

shaped hook. The free end of the egg is furnished with a cap, or lid, which bears at its apex in the center a long, lashlike appendage. This cap is pushed off by the young when it issues from the egg. The eggs are fastened very tightly to the feathers of the fowl.

The incubation period has not been definitely determined. Mr. Bües, in an unpublished thesis on two external parasites of the hen, says that the eggs of *M. pallidum* hatch in from six to ten days. From the context the writer infers that the period was never definitely determined, owing to the fact that no eggs were obtained the age of which was definitely known. At Ames, Iowa, P. H. Rolfs collected eggs of a species of bird lice, *Nitzschia pulicaris*, from the chimney swift. Some of these eggs were kept in a pasteboard box in Mr. Rolfs' vest pocket, while others were placed in glass tubes stopped with cotton and kept underneath a sitting hen. Under these conditions the eggs hatched in from thirteen to twenty days. As in the case first mentioned, the age of the eggs when collected was not known. It is reasonable to suppose that the eggs do not hatch as quickly in winter as in summer; it is certain that lice do not increase as rapidly on fowls in winter as in the warmer seasons. The important point that seems to be established is that the eggs hatch in a few days, and consequently any treatment given to fowls in order to rid them of lice must be repeated in ten days or two weeks.

The young are almost white when they emerge from the eggs; but as they grow older the skin becomes chitinized, brown in color, and in many species bears certain conspicuous brown and black spots and bands, which form rather characteristic markings. The young resemble the parents in shape and appearance, although the head is usually large in proportion to the body and the abdomen is short and stout.

So far as the writer is aware, the number of molts has never been definitely determined for any species. Theobald says, "Some kept by the author molted as many as twelve times, but this surely must be exceptional." The length of the nymphal stages has not been determined. It seems probable that the adult lice live for a considerable time on the hosts. Theobald, using fresh feathers, has kept alive for nine months the species *M. pallidum*, common on the hen.

SPECIES OF LICE REPORTED AS FOUND ON FOWLS

The following list of Mallophaga contain, so far as the writer has been able to determine, all the species that have been reported by different authors as infesting the various domestic fowls named. It is doubtful whether all the species here enumerated have actually been taken from the hosts listed. On the other hand, there are probably undiscovered forms on domestic fowls yet to be reported.

Summary of the species

The hen (*Gallus domesticus*)

Menopon pallidum Nitzsch
Menopon biseriatum Piaget
Lipeurus variabilis Nitzsch
Lipeurus heterographus Nitzsch
Goniocotes hologaster Nitzsch
Goniocotes gigas Tasch.
Goniocotes burnettii Pack.
Goniodes dissimilis Nitzsch
Goniodes eynsfordii Theobald
Goniocotes hologaster Nitzsch var. *maculatus* Tasch.

Professor V. S. Kellogg informs the writer that *Menopon pallescens* Nitzsch and *Goniodes truncatus* Nitzsch are also parasites on the domestic fowl.

The goose (*Anser domesticus*)

Docophorus icterodes Nitzsch var. *adustus* Bur.
Lipeurus jejunus Nitzsch
Lipeurus anseris Gurlt
Trinoton lituratum Nitzsch
Trinoton conspurcatum Nitzsch
Trinoton conspurcatum Nitzsch var. *continuum* Piaget

The duck (*Anas domestica*)

Docophorus icterodes Nitzsch
Lipeurus squalidus Nitzsch
Lipeurus heterographus Nitzsch
Menopon obscurum Piaget
Trinoton luridum Nitzsch

The turkey (*Meleagris gallopavo*)

Goniodes stylifer Nitzsch
Lipeurus polytrapezius Nitzsch
Menopon biseriatum Piaget

The peafowl (*Pavo cristatus*)

Menopon phaeostomum Nitzsch
Goniodes falcicornis Nitzsch
Goniodes parviceps Piaget
Goniocotes rectangulatus Nitzsch

The pigeon (*Columba domestica*)

Menopon biseriatum Piaget
Menopon longicephalum Kellogg
Menopon latum Piaget
Lipeurus baculus Nitzsch
Goniocotes compar Nitzsch
Goniodes minor Piaget
Goniodes damicornis Nitzsch
Colpocephalum longicaudum Nitzsch

The guinea fowl (*Numida meleagris*)

Menopon pallidum Nitzsch
Menopon numidae Giebel
Lipeurus numidae Denny
Goniodes numidianus Denny
Goniocotes gigas Tasch.
Goniocotes hologaster Nitzsch

The hen (Gallus domesticus)

1. ***Menopon pallidum*** Nitzsch, in Giebel Ins. Epizoa, p. 291 (1874).
1668. *Pulex capi* Redi, Experimenta, Tab. 16, Fig. 1.
1788. *Pediculus gallinae* Linné, Syst. Nat. (13th ed.), Vol. 1, Part 5, p. 2920.
1815. *Nirmus trigonocephalus* von Olfers, De Veg. et Anim. Corp., p. 90.
This is the common louse on hens. It has been present, in greater or less numbers, on every fowl the writer has examined, and has a wide geographical distribution.

2. ***Menopon biseriatum*** Piaget, Les Pediculines, p. 469 (1880).
1793. *Pediculus meleagridis* Panzer, Fauna Insect. Germ. 51, Fig. 20.
1818. *Menopon stramineum* Nitzsch, Germar's Mag. Ent., Vol. 3, p. 300.
This is perhaps the next species in order of prevalence. It has a wide distribution.

3. ***Lipeurus variabilis*** Nitzsch, in Giebel Ins. Epizoa, p. 219 (1874).
1788. *Pediculus caponis* Linné, Syst. Nat. (13th ed.), Vol. 1, Part 5, p. 2920.
This is also a fairly common species on the hen and is widely distributed. It is common at Ithaca.

4. ***Lipeurus heterographus*** Nitzsch, in Giebel Ins. Epizoa, p. 218 (1874).
This species has been found at Ithaca and in Mississippi.

5. *Goniocotes hologaster* Nitzsch, in Giebel Ins. Epizoa, p. 184 (1874).
1778. *Ricinus gallinae* DeGeer, Mémoires des Insectes, Vol. 7, p. 79, Tab. 4, Fig. 15.
This is not the *hologaster* of Denny. The insect is found at Ithaca and has been collected at Agricultural College, Mississippi. The variety *maculatus* Tasch. also occurs on the hen.

6. *Goniocotes gigas* Tasch., Die Mallophogen, etc., p. 77, Taf. 2, Fig. 1.
1842. *Goniocotes hologaster* Denny, Monog. Anoplur. Brit., p. 153.
1880. *Goniocotes abdominalis* Piaget, Les Pediculines, p. 238.
This species is certainly not common, although the writer has collected it once in Ithaca on the guinea fowl and Bües has found it in Ithaca on the hen.

7. *Goniocotes burnettii* Pack., Amer. Nat., Vol. 4, p. 94 (1870).
Professor Osborn thinks this species, described by Packard, is *Lipeurus heterographus*. The writer has not seen the type specimen.

8. *Goniodes dissimilis* Nitzsch, in Giebel Ins. Epizoa, p. 201 (1874).
This species is apparently rare, although Railliet and Neveu-Lemaire say it is "très commun sur les poules." The writer has not collected it.

9. *Goniodes eynsfordii* Theo., Journal S. E. Agr. Coll., No. 5 (1896?)
This is a comparatively new species, found in England and described by F. V. Theobald.

Menopon pallescens Nitzsch and *Goniodes truncatus* Nitzsch, according to Professor V. S. Kellogg, have been reported as parasites on the hen.

The goose (Anser domesticus)

1. *Docophorus icterodes* Nitzsch, variety *adustus* Burmeister, Handbuch der Entomologie, Vol. 2, p. 424 (1839).
Piaget apparently regards *D. adustus* as a synonym of *D. icterodes*, or at most not more than a variety. It is *D. adustus* that has been found on the domestic goose. This species has not been collected at Ithaca.

2. *Lipeurus jejunus* Nitzsch, in Giebel Ins. Epizoa, p. 240 (1874).
1668. *Pulex anseris sylvestris* Redi, Experimenta, Tab. 10.
1758. *Pediculus anatis anseris* Linné, Syst. Nat. (10th ed.), p. 612.
1815. *Nirmus crassicornis* von Olfers.
The author has collected this species at Ithaca on the goose.

3. *Lipeurus anseris* Gurlt, in Piaget Les Pediculines, p. 350 (1880).
1842. *Ornithobius anseris* Gurlt, Mag. f. d. ges. Thierheilkunde, Vol. 8, p. 426.
The writer has not collected this species, but has received it from R. S. Bagnall, who collected it on the domestic goose in England. (Journ. Econ. Biol., Vol. 7, No. 1, 1912.)

4. *Trinoton lituratum* Nitzsch, in Giebel Ins. Epizoa, p. 260 (1874).
1842. *Trinoton squalidum* Denny, Monog. Anoplur. Brit., p. 235, Plate 22, Fig. 3.
Denny says he found one specimen on the domestic goose. The writer has not found this species in the United States. The specimen illustrated was loaned by Professor H. Osborn (Fig. 112, page 251).

5. *Trinoton conspurcatum* Nitzsch, in Giebel Ins. Epizoa, p. 258 (1874).
1776. *Pediculus anseris* Sulzer, Geschichte d. Insecten, Tab. 29, Fig. 4.
Denny says this species "is a very common parasite on the domestic goose." The writer has not collected it on the goose. The specimen illustrated was from the snow goose and was loaned by Professor H. Osborn (Fig. 111, page 251).
The variety *continuum* Piaget, Les Pediculines, page 591, also occurs on domestic geese but has not been reported for this country.

The duck (Anas domestica)

1. *Docophorus icterodes* Nitzsch, in Giebel Ins. Epizoa, p. 115 (1874).
1763. *Pediculus dentatus* Scopoli, Entomol. Carniol., p. 383.
This species is common on the duck both at Ithaca and in Mississippi. It must be widely distributed.

2. *Lipeurus squalidus* Nitzsch, in Giebel Ins. Epizoa, p. 241 (1874).
  1805. *Pediculus anatis* Fabr., Systema Ants., p. 345.
  The writer has not been so fortunate as to collect this species from the duck, but there seems to be no doubt about its occurrence on the domestic varieties. It is recorded by Kellogg in his catalogue of Mallophaga, in Genera Insectorum, 66th Fascicule, 1908, p. 44.

3. *Lipeurus heterographus* Nitzsch, in Giebel Ins. Epizoa, p. 218 (1874).
  1870. *Goniocotes burnettii* Pack., Amer. Nat., Vol. 4, p. 94.
  If *G. burnettii* is a synonym of *L. heterographus*, the latter species must be recorded as infesting the domestic duck, because Osborn says specimens from Bruner were from young ducks. It is probable that the lice go from one to another of the fowls when they are in close contact in the same yard.

4. *Menopon obscurum* Piaget, Les Pediculines, p. 497 (1880).
  Neumann records this as occurring on the domestic duck. The writer has not found it on this fowl.

5. *Trinoton luridum* Nitzsch, in Giebel Ins. Epizoa, p. 258 (1874).
  Railliet and Neumann give this species as infesting the domestic duck. The writer has not so found it, but has it from wild ducks. The figure was made from a specimen loaned by the Minnesota Experiment Station.

The turkey (Meleagris gallopavo)

1. *Goniodes stylifer* Nitzsch, in Giebel Ins. Epizoa, p. 200 (1874).
  1781. *Pediculus meleagris* Schrank, En. Ins. Aust., p. 504.
  A common species on the turkey at Ithaca.

2. *Lipeurus polytrapezius* Nitzsch, in Giebel Ins. Epizoa, p. 218 (1874).
  1788. *Pediculus meleagridis* Linné, Syst. Nat. (13th ed.), Vol. 1, Part 5, p. 2920.
  This species also is common on turkeys at Ithaca.

3. *Menopon biseriatum* Piaget.
  The writer has examined material collected by C. Curtice and named *M. stramineum* which is certainly *M. biseriatum*. This material was loaned by the United States Bureau of Animal Industry. The species has been collected at Ithaca on turkeys.

The peafowl (Pavo cristatus)

1. *Menopon phaeostomum* Nitzsch, in Giebel Ins. Epizoa, p. 292 (1874).
  The writer has not collected this species, but at the University of Minnesota there are several specimens collected by O. Lugger. Lugger says, "it seems to be very common."

2. *Goniodes falcicornis* Nitzsch, in Giebel Ins. Epizoa, p. 198 (1874).
  1668. *Pulex pavonis* Redi, Experimenta, Tab. 14.
  1788. *Pediculus pavonis* Linné, Syst. Nat. (13th ed.), Vol. 1, Part 5, p. 2919.
  1815. *Nirmus tetragonocephalus* von Olfers.
  1817. *Ricinus pavonis* Kirby and Spence, Introd. to Ent., Vol. 2, Plate 5, Fig. 3.

3. *Goniodes parviceps* Piaget, Les Pediculines, p. 277 (1880).
  The writer has not collected this species. Piaget found it on the peacock in great numbers.

4. *Goniocotes rectangulatus* Nitzsch, in Giebel Ins. Epizoa, p. 185 (1874).
  The writer incorrectly ascribed this species to Piaget in a list published in the Journal of Economic Entomology, Vol. 6, p. 84, 1913. So far as the writer knows, this species has not been taken in America, but it probably occurs here.

The pigeon (Columba domestica)

1. *Menopon biseriatum* Piaget.
  Neumann says this species occurs on the pigeon. The writer has not collected it on this bird.

2. *Menopon longicephalum* Kellogg, New Mallophaga, Part 2, p. 535 (1896).
  Kellogg collected a male and a female of this species from the domestic pigeon at Lawrence, Kansas.

3. *Menopon latum* Piaget, Les Pediculines, p. 457 (1880).
Piaget records this species on the domestic pigeon and says it is probably the same as *M. giganteum* of Denny (1842).

4. *Lipeurus baculus* Nitzsch, in Giebel Ins. Epizoa, p. 215, 216 (1874).
1668. *Pulex columbae majoris* Redi, Experimenta, Tab. 2.
1788. *Pediculus columbae* Linné, Syst. Nat. (13th ed.), Vol. 1, Part 5, p. 2920.
1815. *Nirmus filiformis* von Olfers, De Veg. et Anim. Corp., p. 90.
1861. *Lipeurus bacillus* Nitzsch (ed. Giebel), Zeitschr. f. ges. Naturwiss., Vol. 23, p. 305.
1870. *Lipeurus angustus* Rudow, Zeitschr. f. ges. Naturwiss., Vol. 36, p. 137.
1874. *Lipeurus antennatus* Giebel, Ins. Epizoa, p. 213.
A very common species on the domestic pigeon. Collected at Ithaca and at Agricultural College, Mississippi.

5. *Goniocotes compar* Nitzsch, in Giebel Ins. Epizoa, p. 183 (1874).
1763. *Pediculus bidentatus* Scopoli (?), Entomol. Carniol, p. 385.
1847. *Philopterus compar* Nitzsch, Walckenaer Hist. Nat. Ins. Apt., Vol. 3, p. 358.
This is a common species found at Ithaca on pigeons nesting about barns and dovecots, generally called domestic pigeons.

6. *Goniodes minor* Piaget, Les Pediculines, p. 256 (1880).
The writer has not collected this species.

7. *Goniodes damicornis* Nitzsch, in Giebel Ins. Epizoa, p. 197 (1874).
Kellogg reports this species on domestic pigeons in the United States.

8. *Colpocephalum longicaudum* Nitzsch, in Giebel Ins. Epizoa, p. 268 (1874).
1842. *Colpocephalum turbinatum* Denny, Monog. Anoplur, Brit., p. 209.
This species was reported by Piaget on the domestic pigeon. Specimens from the pigeon were loaned to the writer by Dr. H. T. Fernald.

The guinea fowl (Numida meleagris)

1. *Menopon pallidum* Nitzsch.
The writer has collected this species at Ithaca on the guinea fowl. It is probable that the insect migrated from hens, with which the guinea fowls were in close relation.

2. *Menopon numidae* Giebel, Ins. Epizoa, p. 292 (1874).
This species has not been collected at Ithaca. The writer incorrectly ascribed this species to Denny in a list published in the Journal of Economic Entomology, Vol. 6, p. 84, 1913.

3. *Lipeurus numidae* Denny, Monog. Anoplur. Brit., p. 115 (1842)
1842. *Nirmus numidae* Denny, Monog. Anoplur. Brit., p. 115.
This species has not been collected by the writer.

4. *Goniodes numidianus* Denny, Monog. Anoplur. Brit., p. 163 (1842).
This species has not been collected by the writer.

5. *Goniocotes gigas* Tasch.
The writer has collected this species at Ithaca.

6. *Goniocotes hologaster* Nitzsch.
The writer has collected this species from guinea hens that roamed among domestic fowls. It was probably a straggler from the latter.

THE COMMON HEN LOUSE (Fig. 96)

(*Menopon pallidum* Nitzsch)

The common hen louse is the species most commonly seen on the hen, and therefore is the best known. It can be found, in greater or less numbers, on almost any hen at any season of the year. Moreover, it passes readily to other domestic fowls that come in contact with the hen, and

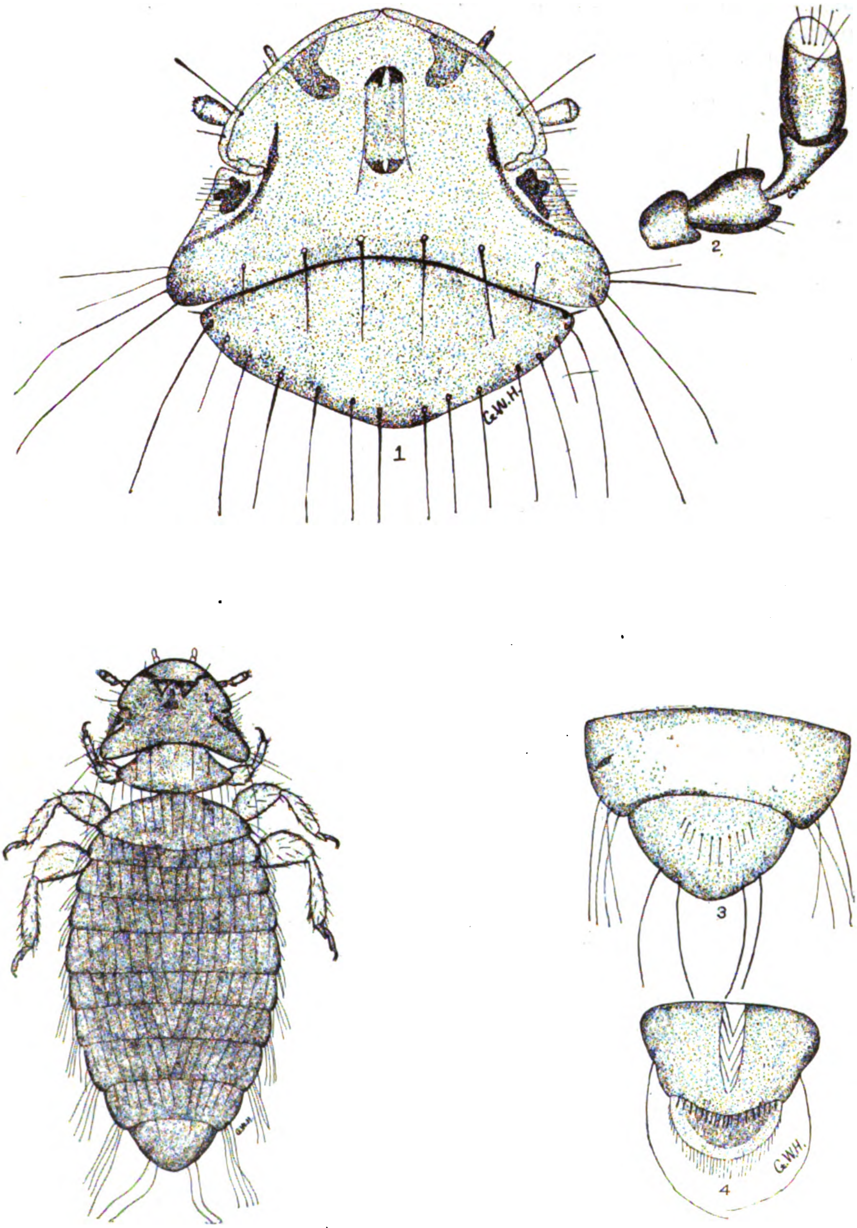

FIG. 96.— *Common hen louse (Menopon pallidum). Male below, at left; 1, head and prothorax; 2, antenna; 3, end of abdomen of male; 4, end of abdomen of female*

instances are recorded in which it has infested horses stabled near hen roosts.

The louse is plainly visible to the eye, being about one-sixteenth of an inch in length. It is of a pale straw color and very active, moving rapidly among the feathers of the fowl. The drawings (Fig. 96) show the main difference between the male and the female insect. In the male the last segment of the abdomen is sharply rounded and bears four long hairs, while the last segment of the abdomen of the female bears a fringe of short hairs. The head of the louse is wider than the thorax, and the eyes are conspicuous.

This insect seems to live on all parts of the fowl's body, but the writer has found it most abundant among the feathers around the vent. It probably causes more injury to hens than does any other species of louse.

THE COMMON LARGE LOUSE OF THE HEN (Fig. 97)
(*Menopon biseriatum* Piaget)

In the experience of the writer, the next commonest louse on the hen is the species called the common large louse. It is much larger than the species first described, and somewhat darker in color. This louse is one-tenth of an inch in length, sometimes slightly longer. The male is larger than the female. It is yellowish in color but is more hairy than *M. pallidum*, there being two transverse rows of hairs on the dorsal side of each abdominal segment. It is usually found in company with *M. pallidum* but is easily recognized by its larger size. The terminal segments of the male differ from those of the female, as shown in the drawings.

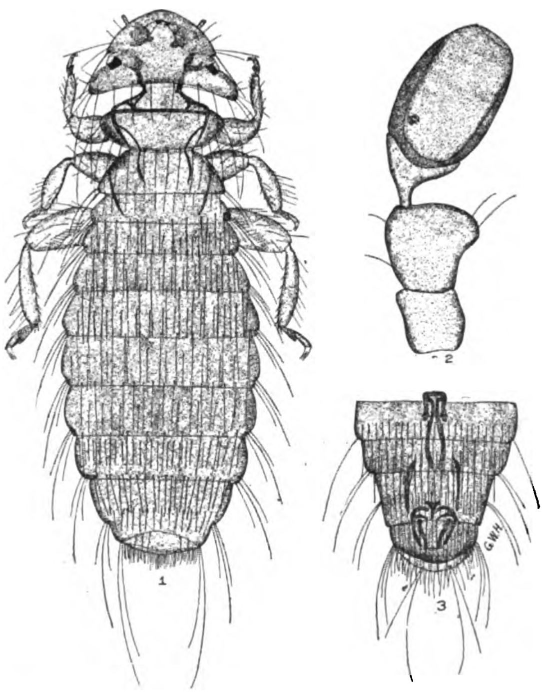

FIG. 97.— *Common large louse of the hen* (*Menopon biseriatum*). *1, Female; 2, antenna; 3, end of abdomen of male*

This species also is active, and apparently passes readily to other hosts for it is found on the turkey and other fowls. It has been present on most of the hens that the

writer has examined, and must cause considerable annoyance and injury because of its size and abundance.

THE VARIABLE HEN LOUSE (Fig. 98)

(*Lipeurus variabilis* Nitzsch)

The variable hen louse has been present in small numbers on many of the hens examined by the writer. It seems never to be abundant, but is usually present. In the experience of the writer it probably stands in abundance next to the two Menopons just discussed. Theobald says, " It is a very abundant species in most breeds of fowl."

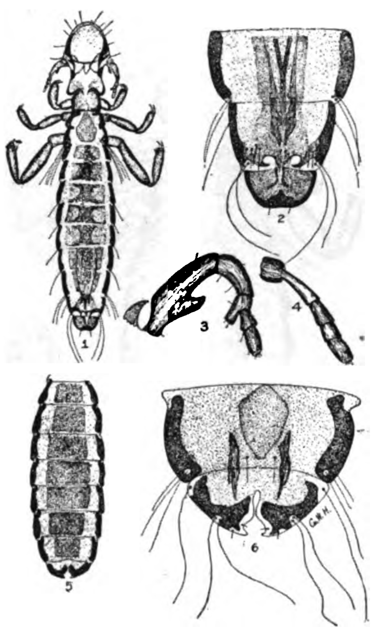

FIG. 98.—*Variable hen louse* (*Lipeurus variabilis*). *1, Male; 2, posterior end of abdomen of male; 3, antenna of male; 4, antenna of female; 5, abdomen of female; 6, last two segments of abdomen of female*

This species has a long, narrow body, with a well-rounded head and prominent antennæ. It is about one-twelfth of an inch in length. It is conspicuous on the body of the hen and can hardly be overlooked. The body of the female is more robust than that of the male. The species is rather darker in color than the two common species previously described. The edges of the body are dark brown in color and there is a dark band down the middle of the abdomen. The antennæ of the male differ strikingly from those of the female (Fig. 98, 3 and 4); in addition, the last segment of the abdomen of the female is bilobed (Fig. 98, 6), while that of the male is bluntly rounded and bears four long, slender, conspicuous hairs.

This louse frequents the primary and the secondary wing feathers of the fowl, although it may be found also on the body. It can move rapidly and is likely to dodge about through the feathers.

THE LARGE LIPEURUS OF THE HEN (Fig. 99)

(*Lipeurus heterographus* Nitzsch)

The large lipeurus can well be called the head louse of the hen. The writer has found it to be fairly common at Ithaca and at Agricultural

College, Mississippi, and most of the specimens that he has collected have been taken from the heads of the fowls. A correspondent sent several fine specimens taken from the head of a cockerel. He said, "They seem to be on the head only, and on the feathers rather than on the skin." Theobald says this species lives in exactly the same manner as the preceding, *L. variabilis*. The writer has collected this species from chickens also, but has been unable to determine definitely whether it constitutes the so-called "head louse" of chickens.

This species is much larger than the variable louse, and is striking in appearance. The abdomen of the female is large and the bodies of both sexes do not appear as long and narrow as those of typical specimens of this genus. The male differs markedly from the female in shape of body, antennæ, and the last segment of the abdomen.

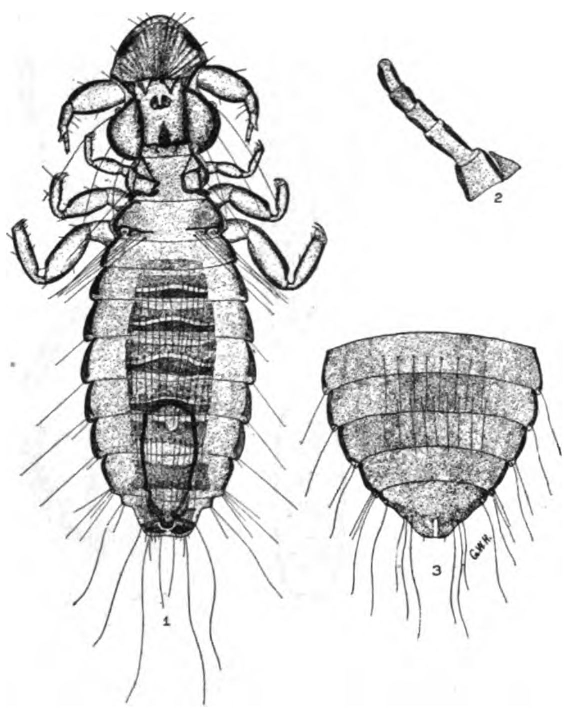

FIG. 99.—*Large lipeurus of the hen* (*Lipeurus heterographus*). *1, Male; 2, antenna of female; 3, posterior end of abdomen of female*

THE LESSER CHICKEN LOUSE (Fig. 100)

(*Goniocotes hologaster* Nitzsch)

The lesser chicken louse, which is usually present in small numbers on hens, is found on the back and the rump particularly, although it may be seen on almost any part of a hen's body. The writer has collected the species on hens at Ithaca and at Agricultural College, Mississippi.

The louse is small, scarcely one-twenty-fifth of an inch in length. The body is short and more or less circular in outline. The markings on the segments of the abdomen are conspicuous but do not extend deeply inward. The posterior segments of the abdomen of the male and the female differ, as shown in the drawings.

THE LARGE CHICKEN LOUSE (Fig. 101)
(*Goniocotes gigas* Tasch.)

The large chicken louse has been confused with the preceding species, but it is nearly, if not quite, three times as large and is a very striking species. It is certainly not so common as *Menopon pallidum*, but the writer has specimens collected in Ithaca from hens and from the guinea fowl.

The insect is nearly one-eighth of an inch in length (3 millimeters), and the male is yellowish brown in color with conspicuous blackish transverse bands extending inward from the margins of the abdomen and a dark band down the middle of the back.

The specimen found on the guinea fowl was on the side of the body, and whether this species frequents any particular part of the fowl's body the author does not know.

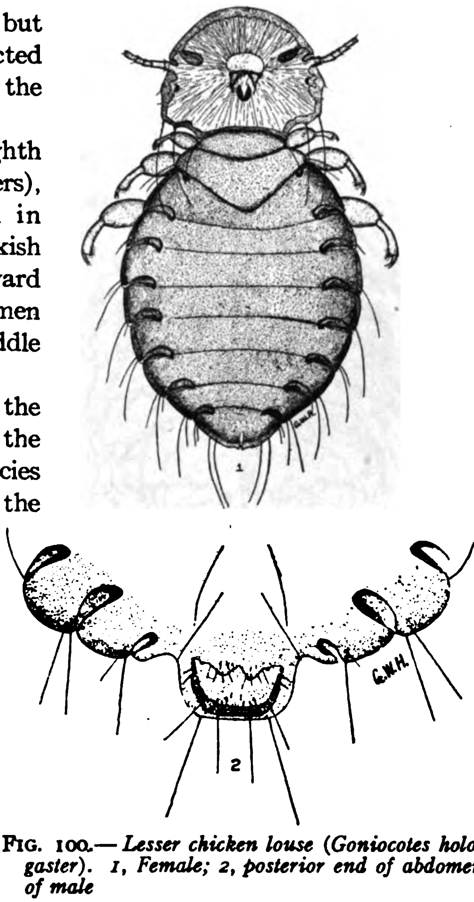

FIG. 100.—*Lesser chicken louse (Goniocotes hologaster). 1, Female; 2, posterior end of abdomen of male*

THE CHICKEN GONIODES
(*Goniodes dissimilis* Nitzsch)

The chicken goniodes is also a large species, but is apparently not common. The writer has never collected it, and, so far as he knows, it has not been reported in America although it probably can be found here. Denny in 1842 considered it of rare occurrence, but Theobald in 1896 says that in England it is an "abundant species on most varieties of fowls, and is especially located under the wings and on the rump." Both Railliet and Neveu-Lemaire say this species is "très commun sur les poules."

THE COMMON LOUSE OF THE GOOSE (Fig. 102)
(*Lipeurus jejunus* Nitzsch)

The common louse of the goose here described has been collected by the writer at Ithaca in considerable numbers, thirty specimens having been

taken from one goose, representing all stages from young to adult. These lice are found among the primary and the secondary wing feathers of geese. They have the habit of gliding sidewise and dodging from one side of the feather to the other through spaces between the barbs.

The louse is long, narrow, slender, and pale yellowish in color with dark margins. The male differs from the female in the form of the antennæ and the last segment of the abdomen. The length of the female's body is over one-eighth of an inch (3.48 millimeters), while the width is only about one-fortieth of an inch (.66 millimeter).

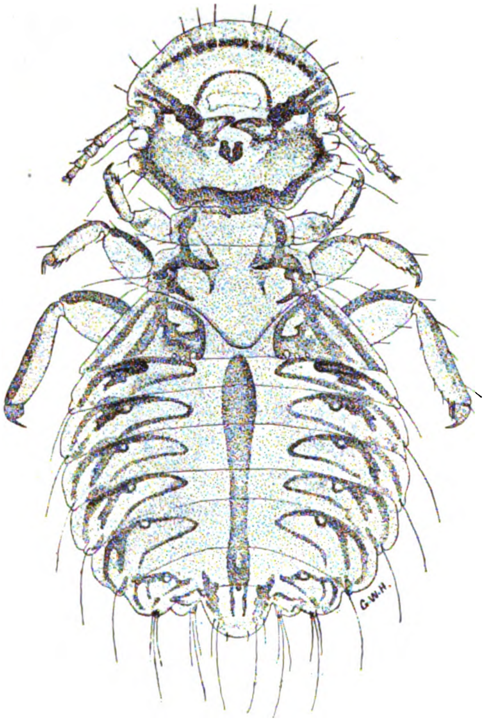

FIG. 101.— *Large chicken louse* (*Goniocotes gigas*), *male*

(*Lipeurus anseris* Gurlt)

The writer has received some specimens of *Lipeurus anseris* from R. S. Bagnall, of England. This species has not been collected in America, nor can the writer find any distinctive characteristics which differentiate it from *L. jejunus*.

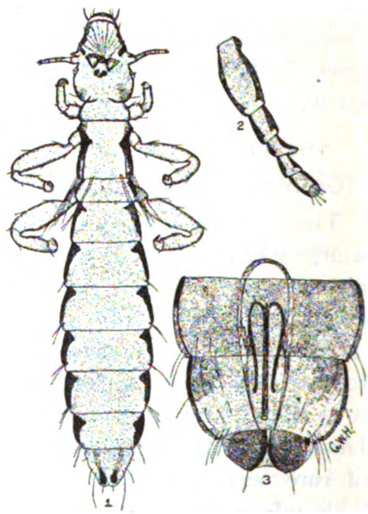

FIG. 102.— *Common louse of the goose* (*Lipeurus jejunus*). *1, Male; 2, antenna of male; 3, posterior end of abdomen of male*

THE COMMON LOUSE OF THE DUCK (Fig. 103)

(*Docophorus icterodes* Nitzsch)

The common louse of the duck has been collected by the writer both at Ithaca and at Agricultural College, Mississippi. It has been found principally on the head of the duck, although it is sometimes seen on the

body. At one time the writer found eight specimens, of which six were females and two were males, on the head of a white peking duck.

The female louse is about one-sixteenth of an inch long. It is rather dark-colored, with dark transverse bands on the abdomen.

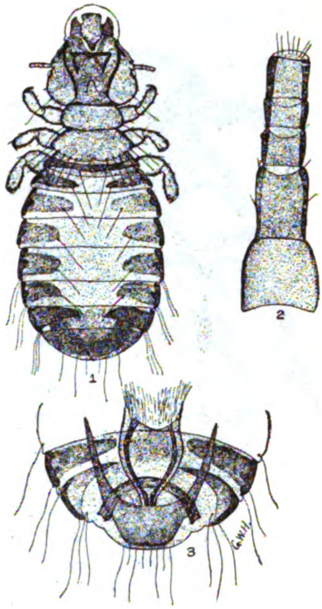

FIG. 103.— *Common louse of the duck* (*Docophorus icterodes*). *1, Female; 2, antenna of female; 3, posterior end of abdomen of male*

THE SQUALID DUCK LOUSE (Fig. 104)

(*Lipeurus squalidus* Nitzsch)

The species known as the squalid duck louse is common on many varieties of ducks, and there seems to be no doubt that it lives on the domestic varieties of ducks although the writer has been unable to find it on this host. Railliet records it as "très commun sur le canard domestique." Kellogg (66th fascicule, *Genera Insectorum*, page 44) records it as occurring on *Anas domestica*.

The squalid duck louse is very characteristic in appearance. It is long and slender, with a pale abdomen marked along the edges with more or less quadrangular dark patches, each patch with a light spot in the center. The body of the female is fully an eighth of an inch in length (3.4 millimeters). The particular specimen illustrated was from a mallard duck and was loaned from the collection of the Minnesota Experiment Station.

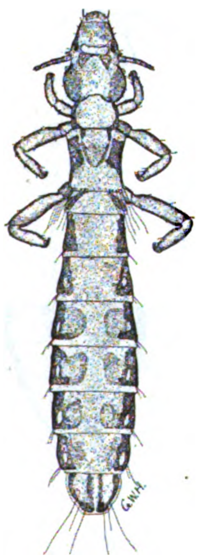

FIG. 104.— *Squalid duck louse* (*Lipeurus squalidus*)

THE LARGE TURKEY LOUSE (Fig. 105)

(*Goniodes stylifer* Nitzsch)

Of all the lice that infest the turkey, the large turkey louse has been found by the writer oftenest and in greatest numbers. It is a striking species in appearance, both in shape and in size. The female is fully an eighth of an inch (3.4 millimeters) in length, chestnut-yellow, and with the hind angles of the head projecting backward to an extraordinary length in the shape of hornlike extensions. The sexes differ from each other in the shape of the antennæ and of the last abdominal segments.

This species frequents the head, the neck, and the breast of the turkey.

THE SLENDER LOUSE OF THE TURKEY (Fig. 106)

(*Lipeurus polytrapezius* Nitzsch)

The slender louse also is common on the turkey, having been found in considerable numbers on the fowls examined. It is a long, slender insect, fully one-eighth of an inch in length (3.46 millimeters). The sides of the abdomen are edged with black, although the general color of the louse is yellowish white.

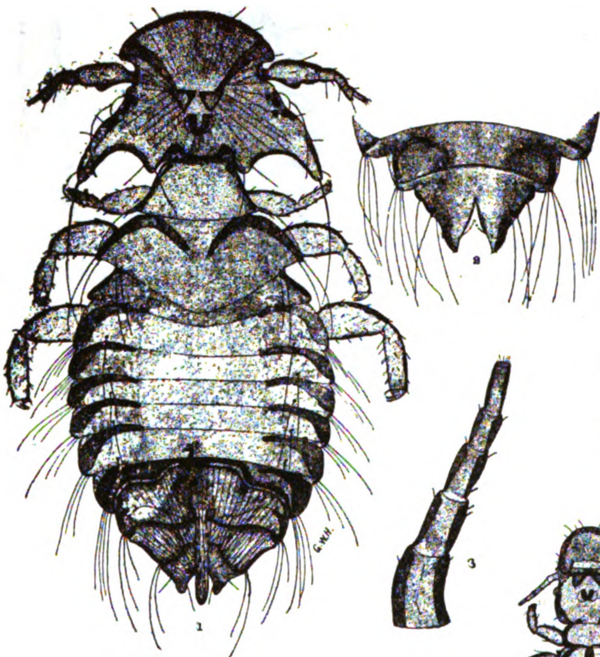

FIG. 105.— *Turkey louse (Goniodes stylifer). 1, Male; 2, posterior end of abdomen of female; 3, antenna of female*

These lice are found on the primary wing feathers and are adroit in dodging from one side of a feather to the other. Denny describes their mode of progression well when he says: "They slide as it were sideways extremely quick from one side of the fiber of a feather to the other, and move equally well in a forward or retrograde direction, which, together with their flat polished bodies, renders them extremely difficult to catch or hold."

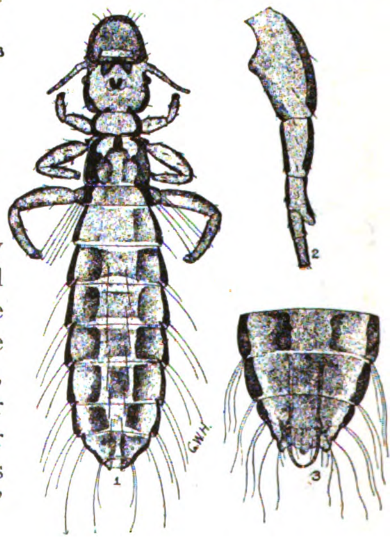

FIG. 106.— *Slender louse of the turkey (Lipeurus polytrapezius). 1, Female; 2, antenna of male; 3, posterior end of abdomen of male*

THE PEACOCK GONIODES (Fig. 107)

(*Goniodes falcicornis* Nitzsch)

The peacock goniodes is apparently a common species on the peacock. It is a large louse, being fully one-eighth of an inch in length. The ab-

domen is short, wide, and rounded. It is marked with dark bands extending inward from the edges of the segments. This species has been found in America, but the writer has had no opportunity to examine the host fowl.

The drawing was made from a specimen loaned by Professor H. Osborn.

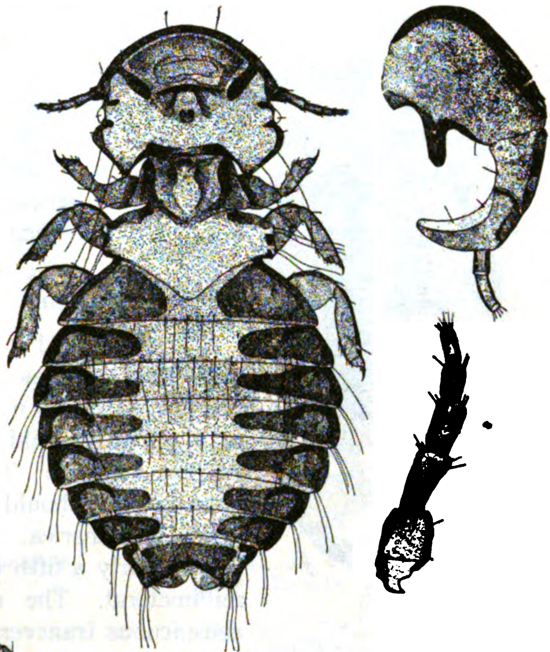

FIG. 107.—*Peacock goniodes* (*Goniodes falcicornis*,) *female. Antenna of male above, at right; antenna of female below*

THE SLENDER LOUSE OF THE PIGEON (Fig. 108)

(*Lipeurus baculus* Nitzsch)

The slender louse of the pigeon is found in abundance on at least "nineteen of the forty pigeon host species." It has been seen on every domestic pigeon that the writer has examined or that has been examined by his students.

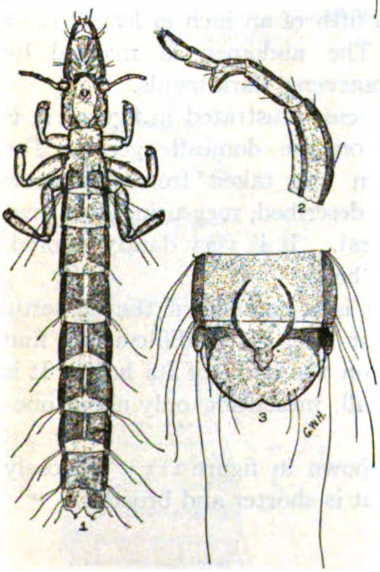

FIG. 108.— *Slender louse of the pigeon* (*Lipeurus baculus*). *1, Female; 2, antenna of male; 3, posterior end of abdomen of male*

The body of this louse is long and narrow, and edged with a dark border on each side. It is only about one-twelfth of an inch in length. It is nearly of the same width throughout the length of the abdomen, although it may be slightly wider near the middle.

This species seems to be confined to pigeons and apparently does not spread to other fowls.

THE PIGEON LOUSE (Fig. 109)

(*Goniocotes compar* Nitzsch)

Denny reports the pigeon louse as "a common parasite on all varieties of domestic pigeons." Osborn says it is a species that has been familiar

for a long time, and is generally common on domestic pigeons. It has been found at Ithaca on pigeons that were generally considered domestic; at least, the specimens were taken from pigeons nesting and living about barns and dovecots.

The insects are small, about one-twentieth of an inch in length. The sexes differ markedly in the form of the last abdominal segment. This species somewhat resembles the small *G. hologaster* of the hen.

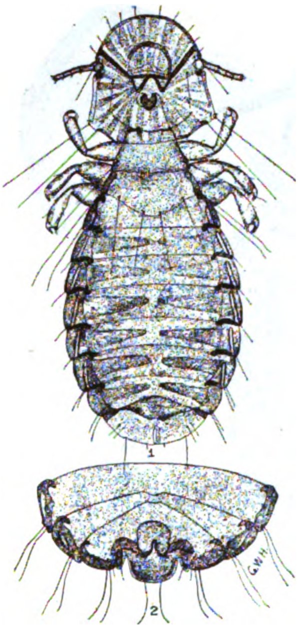

FIG. 109.—*Pigeon louse (Goniocotes compar). 1, Female; 2, posterior end of abdomen of male*

SOME OTHER LESS COMMON LICE

The large bird louse shown in figure 110 is said to infest domestic ducks, but the writer has not yet found it on these fowls. It occurs on many of the wild ducks and has been found on the mallard. There seems to be every reason why it should be found on the domestic duck in America. It is a striking species, being nearly a fifth of an inch in length (4.95 millimeters). The abdomen is marked by conspicuous transverse dark bands.

The large species illustrated in figure 111 is said to occur on the domestic goose. The specimen shown was taken from the snow goose. It is larger than the species just described, measuring over one-fifth of an inch in length (6.25 millimeters). It is very darkly colored, and has large, strong legs and a prominent head.

The pale louse of the goose (Fig. 112) is a parasite of the domestic goose, but evidently not a very abundant one. It is difficult to find among the thick feathers and the down on the body of its host. It is pale in color, almost transparent, and small, measuring only about one-thirty-fifth of an inch in length.

The common louse of the peafowl is shown in figure 113. It closely resembles the common louse of the hen, but is shorter and broader.

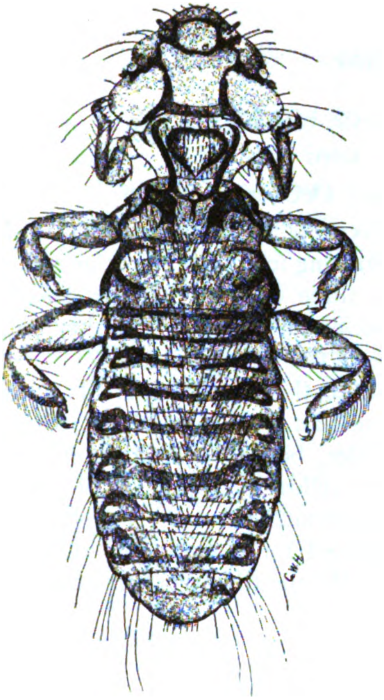

FIG. 110.—*A large louse of the duck (Trinoton luridum)*

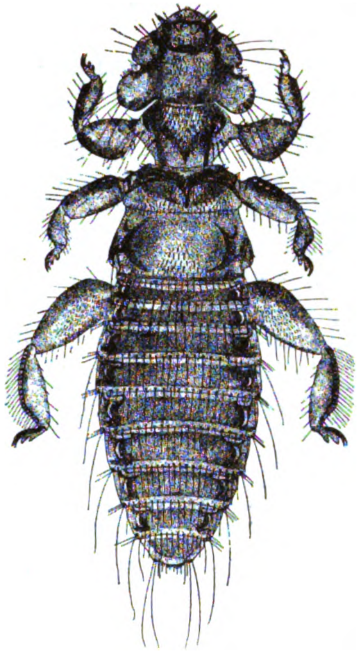

FIG. 111.—*A large louse of the goose (Trinoton conspurcatum)*

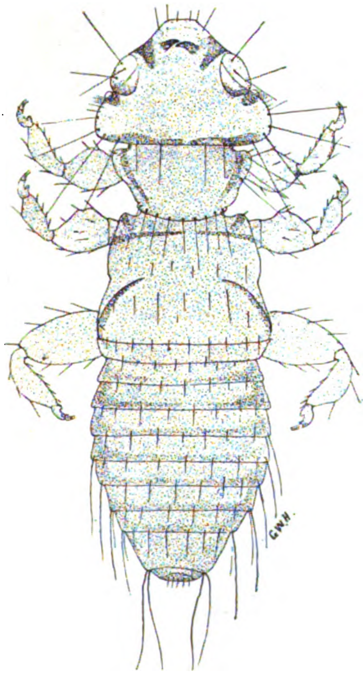

FIG. 112.—*The pale louse of the goose (Trinoton lituratum)*

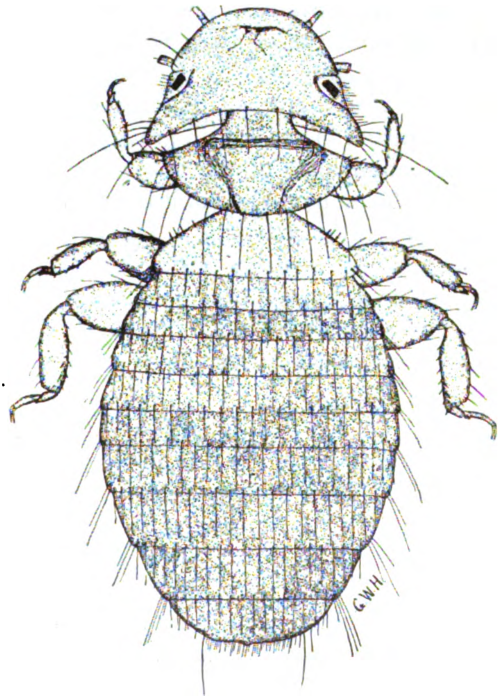

FIG. 113.—*A common louse of the peafowl (Menopon phaeostomum)*

OTHER PARASITES OF FOWLS

THE POULTRY MITE

(*Dermanyssus gallinae* DeGeer)

There are at least eighteen different species of mites parasitic on fowls. Some of these species are merely blood-sucking insects, while others cause affections of the skin. Not more than three or four of them become serious pests, as a usual thing. The species known as the poultry mite is one of the blood-sucking forms and one of the larger species.

The full-grown mites are plainly visible to the unaided eye. It would take about thirty-six of the females to reach an inch, they being .70 millimeter long; the males are slightly smaller, being .60 millimeter long. The color of the mites varies from whitish yellow normally, to blood red when fully engorged. In the female the mouth parts are elongated in the form of long stylets, and are thus fitted for piercing the skin and sucking the blood of the host; in the male the mouth parts are more jaw-like, similar to those of spiders.

Distribution and abundance

The poultry mite is widely distributed over the globe. It has been reported from England, France, Italy, South Africa, Brazil, and all parts of the United States. The writer has found the mite more abundant in the Southern States than in the northern part of the United States. This is probably due to the long and warm summer seasons, with mild winters, which give an opportunity for the mites to survive in greater numbers and increase with greater rapidity.

The abundance of the mites, under certain conditions, almost passes belief. They have the habit of congregating in bunches, like bees settling on a limb when swarming. The writer has seen them hanging in festoons from the nest boxes of sitting hens. In such cases they spread over the perches and become abundant everywhere in the poultry house. There are probably few poultry houses in this country that are entirely free from these mites during the summer months.

Habits and injuries

In contrast with the lice, poultry mites are temporary, not permanent, parasites. They are nocturnal in habit, attacking the fowls at night but forsaking their hosts in the morning and hiding in cracks and crevices of the perches, the nest boxes, and the walls of the poultry house during the day. During the night the mites swarm over the fowls, gorge themselves with blood, and cause serious irritation to their hosts, with an accompanying loss of rest and sleep.

There is no question but that the food of these mites consists largely, if not wholly, of blood. They are often found in great numbers among chicken droppings, but there is no clear evidence to show that they can live on this material or on the juices extracted from it. They can live for a long time without food. Bües kept them alive in a pill box for three months, and Neri maintained them without food for two months. There seems to be authentic proof of their having existed in unoccupied poultry houses throughout a single season at least.

The effect of the mites on fowls is serious and far-reaching. Repp says[3]:

"My observations have demonstrated that chickens infested with mites are exceedingly unprofitable. The cost of keeping them is increased and the income from them is very much reduced. Indeed, when very badly infested they are totally incapacitated for performing work.

"The hens will cease laying. The ovaries undergo atrophy and on autopsy will be found shrunken and in a condition unsuitable for work. In several flocks on which I made observation I found that egg production was greatly reduced or altogether prevented during the spring and summer when, under normal conditions, it would have been at its height."

Almost invariably, the nest of a hen set after the first of May in the latitude of Mississippi will in a few days be found swarming with multitudes of these tiny mites.[4] If the mites are left undisturbed the hen will leave the nest in sheer desperation. This is a sufficient indication of the ability of the mites to cause trouble, for when a sitting hen leaves a nest of her own accord there must be great provocation.

Sitting hens occasionally succumb to the attacks of these mites, from impoverishment of the blood. Repp mentions three cases in which sitting hens died on the nest from no other cause, so far as he could find, than the attacks of mites. Newly hatched chicks are likely to suffer severely in cases of such infestations, and chickens both young and old will become weakened and unthrifty and subject to the attacks of various disorders.

Life history

The following brief notes on the life history of the poultry mite are based on the observations of Bües[5] in New York and of the writer in Mississippi.

The eggs are laid in the hiding places of the mites and mixed with the exuviæ and other débris in the cracks and crevices. Sometimes several eggs are piled together in a bunch. The egg is white, slightly iridescent, and oval in shape. It varies much in size. Bües says the eggs are laid

[3] Repp, John J. The chicken mite. Iowa State College Exp. Sta. Bul. 69. 1903.
[4] Herrick, G. W. The chicken mite. Mississippi Agr. Exp. Sta. Bul. 78. 1902.
[5] Bües, C. R. A. Two external parasites of poultry. Unpublished thesis, Cornell University. 1906.

singly, at the rate of about one a day. His records show that the period of incubation when the eggs were carried in his pocket was from three to three and a half days. In a warm room in the insectary, the incubation period in November varied from four to five days.

The young mite when it hatches from the egg is white in color, and is delicate in appearance but active. It has six legs in this stage but after the first molt the fourth pair of legs appears. Bües believes there is but one molt before the eight-legged stage is reached and several after that stage, although he was unable to determine the exact number. The length of time from egg to adult varies, apparently according to the supply of food. There are several generations in the warm season and they increase with exceeding rapidity.

Control

The poultry mite, like the hen flea, prefers dark, filthy, crowded hen-houses, where it can remain undisturbed and increase without hindrance. Measures to be taken against this pest are discussed at length on pages 747 to 750.

THE COMMON HEN FLEA (Fig. 114)

(*Ceratophyllus gallinae* [Schrank] Wagner)

Heretofore the common hen flea seems to have been definitely recorded but once in the United States. That was by C. F. Baker,[6] who had a single specimen, taken at Ames, Iowa, by Professor Herbert Osborn. The host was not mentioned. This flea has been reported from Bryan, Texas, as common and troublesome on chickens.[7] Baker, however, believes this determination "an erroneous one, the record probably referring to *Sarcopsylla gallinacea*."

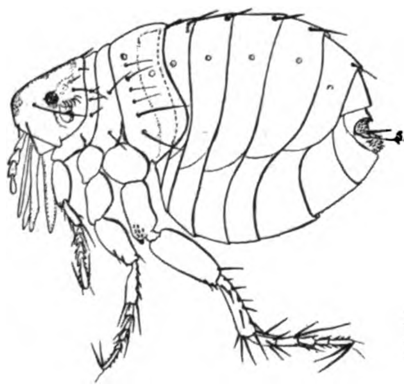

FIG. 114.— *The common hen flea, Ceratophyllus gallinae*

Curiously enough, the writer has received specimens of the common hen flea from two different localities within the last two years. In 1912 specimens were received from a correspondent in Abington, Massachusetts, with the following comments: "It made its appearance on our premises last summer, several weeks after we bought some pullets from a neighbor

[6] Baker, C. F. Preliminary studies in Siphonaptera.—III. Can. ent. 27:111. 1895.
[7] Francis, M. Veterinary science: IV. Notes on parasites. Texas Agr. Exp. Sta. Bul. 30:452. 1894.

who had returned from California three or four years previously. We had never seen anything of the kind up to that time." The specimens sent were caught on the walls and the ceiling inside the henhouse. They were submitted to the Honorable N. Charles Rothschild, of London, England, who identified them as *Ceratophyllus gallinae*.[8] In the following year specimens of the fleas were received from Barker, New York. These were collected from "a hen's nest in the henhouse where these fleas live and breed." There are thus two definite records of the appearance of this flea in the United States, and doubtless it may be found in other localities. Both correspondents state that it is a very annoying pest, especially to human beings. One says: "They have certainly bitten me severely and my husband also. They poison me so that the bite will be troublesome for two or three weeks afterwards." The other says: "When one gets an opportunity to bite it will bite several times in a short distance. The bites soon become much swollen, are red, and itch intolerably."

Life history

The life history of this flea, according to Theobald, seems to be about as follows: The female lays her small, white eggs in the nests of fowls; the eggs are sometimes found also among the droppings on the floor. In a week or ten days the eggs hatch into the slender, whitish larvæ, which finally attain a length of from one-sixth to one-fourth of an inch. The larval life seems to extend over a period of from ten days to three weeks, the length of this period depending on the temperature and other surrounding conditions. When full-grown the larva finds a crack or a crevice, and there spins a pale silken cocoon which is often covered more or less with dirt. Within this cocoon the larva undergoes its change to the pupa, in a period occupying from ten to twenty-one days. At the end of this stage the pupa transforms to the adult flea, thus completing the life history. There may be successive generations during the season, but the insects probably do not breed through the winter, at least in open poultry houses.

Control

It should be borne in mind that these fleas love dirt, dark places, and generally filthy, unsanitary conditions. The larvæ probably live on the organic matter that they find in cracks and crevices of nests, floors, and walls of the poultry house.

The same methods of control that are practiced against hen lice and mites will prevail against these fleas.

[8] Herrick, G. W. Some external insect parasites of domestic fowls. Journ. econ. ent. 6:84. 1913.

THE SOUTHERN HEN FLEA

(*Echidnophaga gallinaceus* Olliff)

(*Xestopsylla gallinacea* Baker)

The southern hen flea is apparently an introduced form, for it was first described from Ceylon. It is now a common pest from Florida to Texas, and Baker states that it has been found in large numbers on horses at Orangeburg, South Carolina. It has been reported by Judge Lawrence C. Johnson as infesting hens, turkeys, cats, dogs, cattle, horses, and children[9]; but Judge Johnson probably had in mind the true jigger flea, or chigoe — *Dermatophilus penetrans*. The writer has met with the southern hen flea in Mississippi, where it was found attacking sitting hens.[10]

In the summer of 1907 the ground beneath one of the dwelling houses on the campus of the Mississippi Agricultural College became infested with fleas to such an extent that the occupants were greatly annoyed by the pests. On examination the writer found that two species were present beneath the house, the hen flea and the dog flea. The house stood on brick pillars some distance above the ground, and thus gave opportunity for hens to go under, where they would lay eggs and rear chickens. Dogs and cats also had free access to the space beneath the house. In order to obtain relief the space under the house was treated with a thorough dusting of slaked lime, and nothing more was heard from the occupants of the house until the summer of 1908, when the fleas again became troublesome. On investigation a hen was found sitting under the house, and both hen and nest were literally alive with the southern hen flea.

The writer does not mean to say positively that these fleas were annoying the occupants of the house, for no specimen of this species was ever found in the rooms. In fact, the writer was unable to get hold of any of the specimens in the house that were actually causing the trouble.

The fleas on the hen were confined to the face, the ear lobes, and the wattles. These parts of the fowl were almost black with them. By actual count there were one hundred and sixty-four fleas on the right wattle and sixty-five on the right ear lobe, and by estimate there were two hundred or more on the right side of the face. The fleas stood at right angles to the surface, with their heads embedded in the skin, and were not at all easy to remove. They could not be brushed off or scraped off with a knife without hurting the hen. Some were removed by tweezers, but even with the use of these instruments they came off with difficulty.

The fowl was placed in a large box containing some sawdust and kept

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[9] Johnson, L. C. Ent. Soc. Washington. Proc. 1:59, 203–205. 1886 and 1889.
[10] Herrick, G. W. Notes on the hen flea (Xestopsylla gallinacea). Journ. econ. ent 1:355–358. 1908.

there for several days. During this time she managed to free herself from a large number of the fleas by scratching her head with her toes, and it is probable that some of the older, engorged females dropped off to deposit eggs.

Some of the engorged females were dissected and found to contain apparently well-developed eggs. In one were found three white, oval eggs; in another were five. On June 22 two engorged fleas were placed in each of three vials. At half past eight o'clock on the morning of June 23 five eggs were found in vial a, five in vial b, and three in vial c. The eggs were white, oval, and considerably longer than broad. They measured from .35 to .4 millimeter in length.

It appeared to be so easy to obtain the eggs that a more extended observation seemed worth while. Accordingly, on the morning of June 23 one large, apparently engorged, female flea was placed in each of fifteen vials, in order to ascertain their egg-laying capacities. Eggs were obtained in every case but one, and in most cases the larvæ hatched readily, as shown by the following table:

OVIPOSITION RECORD OF HEN FLEA

Fleas placed in vials on June 23	June 24	June 25	June 26
	Number of eggs	Number of eggs	Number of larvæ hatched
Vial a	2	2	2
Vial b	2	2	1
Vial c	1	1	0
Vial d	3	3	3
Vial e	4	4	0
Vial f	7	7	5
Vial g	3	3	0
Vial h	1	1	1
Vial i	4	4	1
Vial j	4	4	2
Vial k	5	5	3
Vial l	4	4	1
Vial m	2	2	0
Vial n	1	1	0
Vial o	3	3	2

It will be seen from the table that the fleas laid all their eggs on the day following their placement in the vials, and that the larvæ hatched within forty-eight hours after the eggs were deposited. At half past nine on the morning of June 26 most of the larvæ were found just wriggling out of the eggshells. Some had not yet got clear of the shells.

The larvæ were white, very active, and from 1.5 to 1.8 millimeters in length. They were nearly of the same diameter throughout, with the thorax slightly larger than the remainder of the body. They were placed in separate vials, containing sawdust, feathers, and filth, but, very likely owing to unfavorable conditions of moisture and temperature, none of them developed.

Judge Johnson says regarding southern hen fleas that "Of the females, however, it is certain they bury themselves in the skin of their victims. From the first, they hold on with such tenacity that no ordinary brushing will remove them. It seems to be at this stage in their existence that impregnation takes place. The males now are often seen in copula with them, and so remain apparently for days, or until the tumefaction of the skin excited by the imbedded female closes around her so as to shove him off. Here ends about all actually known of this history." From the writer's observations this account is very probably accurate, except for the latter part. The males were found present on the head of the fowl, but were not actually observed in copulation with the females, although fecundation may have taken place under these conditions. So far as the writer's observations go, however, no tumefactions of the skin of the fowl take place. Judge Johnson further says: "From analogy, we may infer that, the period of gestation being completed, the gravid female lays her eggs in this well-prepared *nidus*, or, more particularly, that they remain and are hatched in her distended stomach, after which the larvæ crawl out and drop to the ground."

From the ease with which the females were induced to lay eggs in the vials, the writer believes they merely drop off from the host when engorged, as a cow tick does, and lay their eggs among the débris in the nests of the fowls. At no time was there a tumefaction of the skin or a so-called nidus formed. It seems that Judge Johnson must have ascribed the disease known as the wart disease to this flea, or possibly confused it with that caused by *Dermatophilus penetrans*.

THE HARVEST MITE

(*Trombidium* sp.)

The young, or larval, forms of the mites commonly known as harvest mites sometimes attack young chickens. Railliet[11] mentions attacks by the larval forms of *Trombidium holosericeum* on late-hatched chickens, and states that they sometimes produce high mortality. He says the parasites fix themselves at the bases of the feathers, where they insert their rostrums and set up an irritation that produces an epileptiform

[11] Railliet, A. Traité de zoologie médicole et agricole, p. 703. 1895.

affection resulting in death. These young forms of harvest mites are generally known in this country as redbugs, or chiggers.

The writer had opportunity in 1908 to observe the attacks of redbugs on young chickens in Mississippi. The young chickens in the poultry yards of the Agricultural College were attacked in two successive summers by these insects. On May 28, 1908, two young chickens that were evidently diseased were examined, and on the sides of the bodies beneath the wings, where the feathers were scarce, were found here and there rather large red nodules, or tubercles. The nodules were usually capped, around the edges of the top at least, with a hard scab or crust. In the center of the crust of each nodule were found the red, distended abdomens of numerous mites, with their heads buried in the tissues. When the scab was removed the mites came with it, leaving a comparatively large cavity in the center of the nodule.

The mites were evidently gregarious and their presence in such numbers had stimulated the tissues until the nodule had been formed. Within the nodules were masses of whitish, fatlike tissue, composed of long, tapering cells. The mites were almost buried in these masses. Occasionally one isolated mite was found, especially between the secondary quill feathers of the wings. In each case the head of the mite was buried in the flesh of the fowl, as in the case of the ticks.

On June 17 other chickens from the same brood were examined. These were of course somewhat larger than those first examined. On chick 1 several healing nodules were found from which the mites had evidently escaped. Fresh nodules were found, however, on the sides of the body, with mites in them, and there were also isolated mites on the undersides of the wings. On chick 2 there were two large nodules on the right side of the abdomen. One of these contained the bodies of seventeen mites closely packed together like red berries, with their heads embedded in the tissues of the tubercle. On chick 3 a large tubercle was present containing the bodies of nine mites, and on chick 4 a large tubercle contained nineteen mites. On all these chickens there were other smaller clusters of mites, and a few isolated ones on the undersides of the wings.

Specimens of these mites were submitted to Banks for identification. He wrote that they were "Leptus, that is, the larvæ of Trombidium. No species have as yet been bred in this country, so it is impossible to tell to what species your material belongs."

Professor Kerr, of the poultry department at the Mississippi College, observing the effect of these mites on young chickens, says the chicks soon succumb to the attacks of the mites. The chicks seem to contract a diarrhea, grow weaker and weaker, and finally die. Professor Kerr thinks the mites are responsible for a high mortality among chickens in the South.

Control

It is quite probable that harvest mites breed in weeds and tall grass, where the sun's rays cannot penetrate and where moisture conditions are favorable. Young chicks liable to attacks from these mites should be confined to areas kept clear from weeds and tall grass. The mites are not likely to breed in closely cropped grass and in an absence of shade. The heat of the sun would probably prevent their development.

A TICK THAT INFESTS TURKEYS

(*Haemaphysalis chordeilis* Pack.)

Within the past year the following letter, accompanied by specimens, was received from a correspondent in Warren County, New York: "I am sending you a few specimens of bugs. We find them on the turkeys and have found one on a wild partridge. Can you tell us what they are and how to keep them off our turkeys?"

The specimens proved to be a species of tick which Banks identified as *Haemaphysalis chordeilis* Pack. Banks reports but two species of this genus from the United States.[12] One of these, *H. leporis-palustris* Pack., has been reported commonly from the Southern States; the other, *H. chordeilis* Pack., has been reported by Banks from Milton, Massachusetts, and Taftsville, Vermont. The specimen from Vermont was taken from a turkey, and that from Massachusetts was from a nighthawk. In 1909 Hadley [13] reported an infestation of turkeys at Norwich, Vermont, with the same species. He states that at the time of the report of the infestation the turkeys were dying as a result of injuries from the ticks. The ticks were first observed on the young turkeys in the latter part of May, when the turkeys were about one week old. The ticks seemed to cling mostly to the region of the neck. The birds that were infested bore from seventy to eighty mature ticks and as many more immature forms. The owner tried insect powders, lard, and kerosene oil, but without success. He was finally obliged to pick the ticks off by hand.

It is of interest to observe that Norwich is only about twenty miles from Taftsville, where this species on the turkey had already been reported by Banks. Moreover, Bolton Landing in New York is in Warren County and almost directly west of Norwich and Taftsville, at a distance, judging from scale measurements made on a map, of about fifty miles. The writer has been unable to find out whether the correspondent at Bolton Landing, New York, had ever bought turkeys from the vicinity of Windsor or Taftsville, Vermont. In case he had, it would not be difficult to ex-

[12] Banks, Nathan. A revision of the Ixodoidea, or ticks, of the United States. U. S. Agr. Dept., Ent. Bur. Bul. 15, Tech. ser. 1908.

[13] Hadley, Philip B. Notes on the parasitism of Cytodites nudus and Haemaphysalis chordeilis. Science 30:605-606. 1909.

plain the westward distribution. In case he had not, the westward distribution would have to be explained by the supposition that these ticks are already widely distributed in that latitude or that they are gradually diffusing themselves from farm to farm. If the tick found on the partridge (ruffed grouse) was really of this species, the fact would be significant; for if this tick is a parasite of the grouse it might easily find its way to turkeys, since these fowls range widely over field and forest. Unfortunately, the correspondent did not say whether he included among the specimens sent the one collected from the partridge.

This tick is a rather large one, the full-grown female being from one-quarter to five-sixteenths of an inch in length. The body is reddish brown and is almost as wide as it is long.

Control

The introduction of infested fowls from tick-infested areas should be avoided by carefully quarantining and examining all turkeys purchased from other localities before turning them in with the home flock.

If fowls once become infested, hand-picking will probably prove to be the most feasible method of control.

METHODS OF CONTROLLING THE PARASITES OF DOMESTIC FOWLS

The measures of control here recommended are the result of experiments through several years, more especially with the chicken mite in the Gulf States, where it is especially prominent as a pest of domestic fowls.[14] It does not seem desirable to give details of these experiments, but rather to make definite recommendations based on their results.

Lice, chicken mites, and hen fleas are all responsive to much the same line of control treatment. What is effective for one is, broadly speaking, effective for all, though the lice may call for additional and special treatment. The suggestions given cover the methods whereby the parasites discussed in this bulletin may be held in check.

NECESSITY OF CLEAN SURROUNDINGS AND OF LIGHT

From work with the poultry mite and the hen flea extending over several years, the writer is convinced that the most potent cause of the presence and increase of these parasites is filth — under which may be including droppings, decaying and decayed eggs, and bits of decayed material of all kinds. Mites especially are found in great numbers in the filth that has sifted through the straw and that lies in the bottom, in the corners, and in the cracks, of the nest. If a partly hatched egg happens

[14] Herrick, G. W. The chicken mite. Mississippi Agr. Exp. Sta. Bul. 78. 1902.

to be broken in the nest the mites literally swarm over it. The filthier the nest becomes from droppings and broken eggs, the more abundant become the mites.

Lack of light is another cause of the presence and increase of mites and other parasites. Many persons believe that almost anything will answer for a poultry house. The only light that enters many poultry houses is what filters in through cracks and through a small door, which may or may not be allowed to stand open.

Such a house as the one shown in figure 115, facing the south, is almost ideal so far as obtaining the maximum amount of sunshine and air is concerned. The open windows should be fitted with cloth curtains fastened to wooden frames hung on hinges. During the day in pleasant

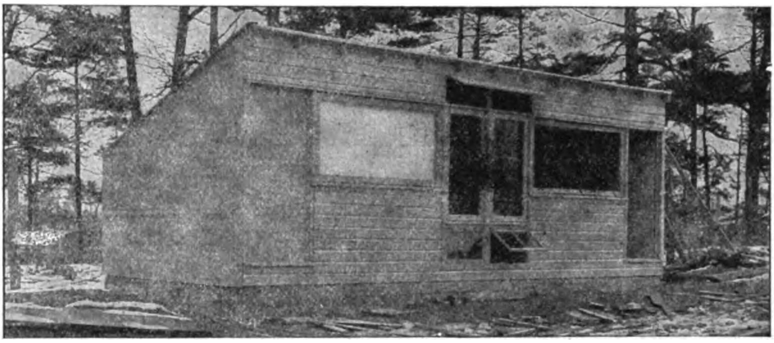

FIG. 115.— *Poultry house providing abundance of light and air*

weather the curtains may be swung up out of the way. At night they may be let down to close the windows, thus making the house warmer but allowing sufficient air to enter for ventilation.

Inside of poultry house[15]

The poultry house should be high enough and roomy enough inside so that one can go in and walk about with some degree of comfort and pleasure. It is a place that should be visited every day in order that it may receive proper attention. A poultry house built in such a way that one has to crawl through a small door in order to enter, and then go groping around in semidarkness, half bent to the ground for fear of bumping the head against the roof, will receive few visits and scant attention.

The inside of the house should be planned so that nearly, if not quite, everything — perches, dropping board, and nest boxes — can be removed,

[15] Herrick, G. W. The chicken mite. Mississippi Agr. Exp. Sta. Bul. 78. 1902.

leaving nothing but the four bare walls. It would be advantageous to have the floor made of concrete. This would aid in insuring dryness, cleanliness, and freedom from parasites. As few pieces of timber as possible should be nailed permanently to the walls of the house, the object being to eliminate everything possible that might afford a hiding place for the parasites and protect them from whatever insecticides might be used. In such a house every part of the walls can be thoroughly treated with kerosene oil, carbolic acid, or any other insecticide. Perches, nest boxes, and other fixtures are also much more easily cleaned and treated if removed from the house than if they are in place.

To clear an infested poultry house of mites

It often happens that a poultry house becomes infested with mites from floor to roof and in every nook and cranny. If the house is of the older type and not too valuable, it may be justifiable to burn it and build anew. In any case the perches and nests should be torn out, in order to facilitate the application of insecticides. The next thing to do is to clean the walls and floors by giving them a thorough sweeping. The inside of the house should then be sprayed with kerosene or crude petroleum. It is best to begin at a certain place and go over walls and floor with the oil, applying it with considerable force by means of a pump and not stopping until every square inch has been covered. The liquid should be forced into cracks and crevices between the boards. The oil will kill all the eggs that are hit, but some eggs will surely escape being touched. As it takes from four to five days for the eggs to hatch, the walls should be gone over again in about a week in order to kill the young mites that appear in the meantime. In another week a third application may be necessary.

If it is thought preferable, the kerosene or crude petroleum may be made into an emulsion[16] and diluted to ten or fifteen per cent, which will kill all the mites actually hit. The emulsion is made as follows: One-half pound of laundry soap or whale-oil soap is shaved fine and dissolved in 1 gallon of water. The soap is best dissolved if the water is nearly or quite at the boiling point. When the soap is dissolved and the water is hot it is removed from the fire, 2 gallons of kerosene oil is added, and the mixture is agitated or churned violently until a white, creamy emulsion is formed. The best way to produce the emulsion is to pump the liquid back into itself through the pump until the mixture becomes creamy. To make a ten-per-cent emulsion 17 gallons of water is added to the 3 gallons of stock mixture; to make a fifteen-per-cent emulsion 10⅓ gallons of water is added to the 3 gallons of stock mixture.

[16] Repp, John J. The chicken mite. Iowa State College Exp. Sta. Bul. 69. 1903.

It is advisable to follow the application of the oil to the walls of the house with a dusting of dry air-slaked lime 3 parts and sulfur 1 part. The windows and doors of the house should be closed and the lime-sulfur should be thrown up to the roof and against the walls until the air is full of the particles. The powder will gradually settle everywhere, much of it entering cracks and crevices.

Isolation of poultry house

It is a well-known fact that the poultry mite sometimes attacks horses, causing sores on the skin and a consequent falling-out of the hair, thus making bald spots at points of infestation. Such attacks on horses by poultry mites occur only when infested fowls have roosted near the stable. Sometimes poultry houses are built adjoining the horse stable, and sometimes fowls are allowed to roost over the horses or even about the mangers. In such cases there is danger of an attack on the horses by mites. For this reason poultry houses should be built at some distance from other farm buildings, especially from horse and cow stables.

ISOLATION OF SITTING HENS [17]

It is customary on many farms to place sitting hens on eggs in the same house with the other fowls. Mites are likely to infest brooding fowls and to increase enormously in the nests of the fowls. It is therefore desirable to have sitting hens apart by themselves, in a separate room or a separate building. It seems not to be a good practice, however, to set hens in boxes and barrels here and there about the grounds, as this often exposes the fowls to the injurious effects of rain and storms. A woman living in Missouri, writing for an agricultural paper, says: "Hens should be set in a room fitted up for that purpose with nests like those in which they lay. When one is ready to sit, and her service is wanted, a clean box should be obtained, treated with kerosene and carbolic acid, and sprinkled with lime, after which a good soft nest should be built therein."

It must be remembered also that sitting hens need some attention. Not infrequently an egg is broken in the nest. When this happens, the egg should be removed and the others with which it has come in contact should be carefully washed with warm water and wiped dry. If there are droppings in the nest they should be removed. It is of advantage to dust fresh insect powder on the hen occasionally while she is brooding. To facilitate the care and handling of a brooding fowl, some attention and thought should be given to the selection of the right kind of a hen.

[17] Herrick, G. W. The chicken mite. Mississippi Agr. Exp. Sta. Bul. 78. 1902.

A quiet, motherly, easily handled hen should be chosen. The idiosyncracies and character of a hen have much to do with her success as a mother.

TREATMENT OF MALE BIRDS

An infested rooster is a fruitful source of distribution of lice and other parasites throughout a whole flock. Particular attention should be paid to ridding male birds of these parasites. It would be well to dust the males occasionally in a thorough manner with the Cornell (Lawry) powder. Moreover, when a new cockerel is introduced into the flock it is a good practice to isolate him for a few days and make two or three thorough applications of the powder, being sure that the bird is free from all parasitic affections and diseases before allowing him to be with the flock.

DUST BATH FOR HENS

Rice says that "a dust wallow is as essential to a fowl's health and happiness as a water bath is to the health of a human being."[18] It is a common thing to see hens and chickens wallowing in dry dust. They make a hollow place in the ground to conform with the body, and in this they lie, scratching with the feet, fluttering the wings, and elevating the feathers until they stand all fluffy and loose over the body. By scratching, the fowls loosen and pulverize the soil, which is worked down in among the feathers. This is not done wholly for pleasure, although the fowls apparently enjoy it; the fine dust is an excellent insecticide and aids in controlling mites and lice.

There are days and seasons of the year when fowls cannot find dry, dusty places in which to wallow. Moreover, where fowls are kept in a pen or a yard they are not always able to find a satisfactory dust bath. In view of these facts a dust bath should be provided and made accessible at all times and seasons.

The finer, lighter, and drier the dust, the more satisfactory it will be. Some kinds of light road dust are good; fine sandy loam is excellent. Whatever soil is used, it is well to lighten it by mixing it with finely sifted coal ashes. It is also advantageous to add now and then small quantities of snuff, sulfur, or dry slaked lime, or all three of these.

The box containing the dust should be set near a window, where the dust will be kept dry and warm and where the sunlight will reach it for a considerable part of the day. The mixture may be kept in an open box, but in this case the fowls that are not dusting are compelled more or less to inhale the particles of dust. Because of the dust's rising, it is of advantage to keep the fine soil in a covered box with a lid on top

[18] Rice, J. E., and Rogers, C. A. Building poultry houses. Cornell Univ. Agr. Exp. Sta. Bul. 274:30, 1910.

for easy filling; a small opening in one side of the box should be provided for the entrance of the fowls (Fig. 116).

DUSTING FOWLS

The measures of control thus far outlined are more especially applicable to the poultry mite, although most of the measures discussed are of value in controlling hen lice also. The lice, as has been pointed out, are permanent parasites and rarely leave their hosts. Therefore applications of oil to the walls of the house, the perches, and other fixtures do not reach the lice on the hens. Light, cleanliness, fresh air, and dust baths are of great value in fighting lice, but it sometimes becomes necessary to actually hit the lice with an insecticide in order to check or destroy them. For this purpose dust insecticides are usually recommended and applied.

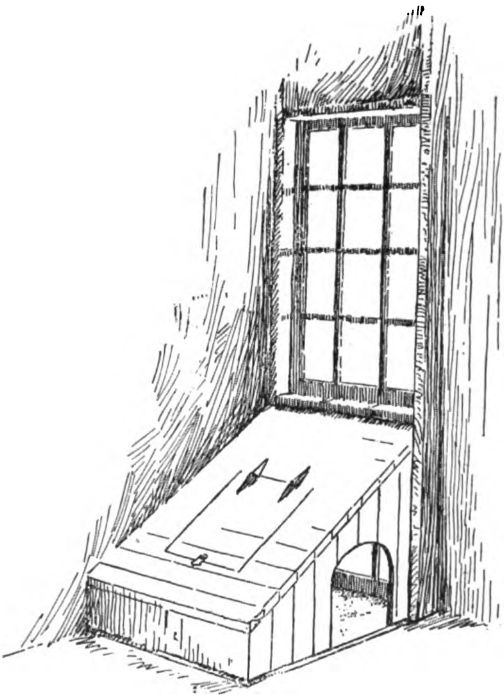

FIG. 116.— *Box for the dust bath*

The best dust insecticide that the writer has ever known is the Cornell (Lawry) powder. It is made in the following way[19]: Two and one-half pounds of plaster of paris is spread in a shallow pan or tray. One-fourth pint of crude carbolic acid is poured into a cup, and into this is poured three-fourths pint of gasoline. The mixture of acid and gasoline is poured over the plaster of paris and thoroughly mixed. It is then rubbed through a wire window screen on a piece of paper and allowed to stand for from one and one-half to two hours or until thoroughly dry. *It must not be placed near a flame or any heat.* The powder should be kept in a closed can or jar, where it will retain its strength for a long time. The powder is applied by means of an ordinary sifter or with the finger, and is worked in among the feathers about the vent, in the fluff, and under the wings. In extreme cases

[19] Circular letter, Department of Poultry Husbandry, Cornell University.

the application should be repeated in about two weeks. A small pinch of the powder is sufficient for a fowl.

Cost of dusting fowls

It seemed desirable to ascertain the approximate cost of dusting hens with the Cornell powder. Several extensive trials were made in cooperation with the Department of Poultry Husbandry. The work of dusting was performed by students, who proved fairly skillful after a little practice. The results of these trials are shown in the table:

COST OF DUSTING FOWLS

Pen no.	7	8	8	11	9	11
Number of fowls	367	175	220	401	228	232
Number of students	7	5	4	4	5	5
Time (in minutes)	82	64	53	70	51	47.5
Powder used (in pounds)	3.7	2.3	4.2	5.3	2.3	3.5
Cost of powder	$.13	$.08	$.15	$.19	$.08	$.09
Cost of labor	$1.45	$.56	$.53	$.70	$.64	$.59
Total cost	$1.58	$.64	$.68	$.89	$.72	$.68
Cost per one hundred hens	$.43	$.37	$.31	$.22	$.32	$.29

It is seen from this table that the average cost of dusting was a little over 32 cents for each one hundred fowls. This is a little less than one-third of a cent for each fowl. Considering the effectiveness of the powder, this is not an excessive amount to spend for controlling lice.

DIPPING FOWLS

The writer has had no experience in dipping fowls, and on general principles would not advise it. The effect on the fowl is rather severe and the shock must be considerable. The following dips have been used: (1) Pure carbolic acid, 1¼ ounces in 1 gallon of hot water. After the solution has cooled, the fowl should be immersed in it for *one minute only*. (2) Creolin at the rate of 2½ ounces to a gallon of water may be used instead of carbolic acid.

MIXTURES FOR PAINTING PERCHES

One of the most convenient mixtures for painting perches, nest boxes, or walls of a poultry house, is a combination of crude carbolic acid and kerosene. Three parts of kerosene and one part of *crude* carbolic acid make an effective mixture for killing eggs, mites, lice, fleas, and any parasites that may be present in cracks and crevices of the house. There is no objection, other than that of the expense, to using this mixture for spraying walls and perches.

Another mixture for painting perches and nest boxes is known as *cresol soap*.[20] It is made by shaving " one ten-cent cake of laundry soap into one pint of soft water. Heat or allow to stand until a soap paste is formed. Stir in one pound of commercial cresol and heat or allow to stand until the soap paste is dissolved. Stir in one gallon of kerosene. Cresol is a coal tar product and may be obtained from the druggist at about 30 cents per pound. Care should be taken not to get any of it upon the hands or face as it will cause intense smarting. For use as a lice paint, apply undiluted."

[20] Pierce, H. C., and Webster, R. L. Lice on fowls. Iowa State College Exp. Sta. Press bul. No. 18. 1909.

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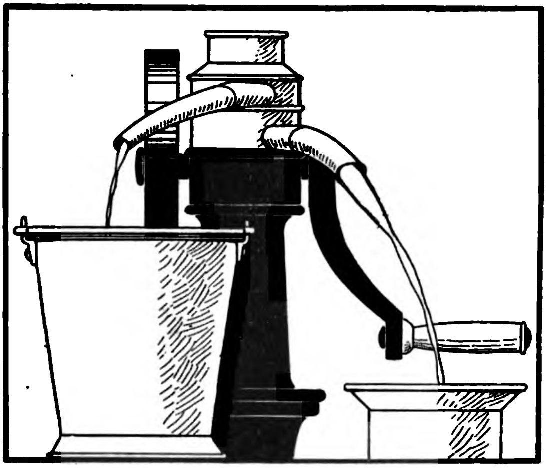
Department of Dairy Industry

VARIATIONS IN THE TESTS FOR FAT IN CREAM AND SKIMMED MILK



BY E. S. GUTHRIE AND G. C. SUPPLEE

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VARIATIONS IN THE TESTS FOR FAT IN CREAM AND SKIMMED MILK

E. S. Guthrie and G. C. Supplee

There are a number of factors that affect the percentage of fat in cream from a centrifugal separator, though many dairymen have the impression that this percentage should be constant if the cream screw or the skimmed milk screw is not changed. Besides this screw (which is a device for regulating the percentage of fat in the cream within only approximate limits), the following factors must be considered: temperature, speed, rate of inflow, percentage of fat in whole milk, variation in amount of liquid used for flushing — or in quantity of whole milk, which amounts to essentially the same thing — and slime deposit.

In the experiments described herein, with the exception of the one on the effect of variation in the amount of flushing liquid, the samples of cream and skimmed milk were taken before the bowl of the separator was flushed. Thus the possible effect of a variation in the test caused by different quantities of skimmed milk used in flushing was eliminated. Unless otherwise noted, the samples were taken from the containers at the completion of the run. One can of milk, amounting to from eighty to eighty-five pounds, was used in each determination unless otherwise stated. The tests were made in duplicate.

All the factors were studied with one machine, which is designated as separator 1. Some of the factors were studied later with other styles of separators, but not so many determinations were made. Five different types of separators, representative of the machines in common use, were employed in these experiments.

All the milk was standardized to a definite percentage of fat, and unless otherwise noted it was made to test 4 per cent fat. In order that the viscosity of the milk might not be affected, the standardization was not accomplished by using skimmed milk and cream from a centrifugal separator, but by allowing whole milk to separate by gravity and thus obtaining the proper mixture of cream and skimmed milk.

During all the runs, with the exception of those made in the study of the effect of different quantities of milk in the supply tank, the tank was kept about half full. At the end of a run it was allowed to empty before the samples were taken. A uniform pressure was insured by placing a second supply tank from another separator on a frame above the first tank and properly regulating the gate in the second tank.

The reader should understand that so much exactness is not necessary in the control of the conditions affecting separation as was used in these experiments, for a slight variation, which might affect a scientific study, would not detract from the efficiency of a separator.

In the operation of the separators the steps were: (1) the milk was standardized; (2) the separator was put in proper running condition; (3) forty quarts of milk was obtained; (4) the temperature of the milk was raised to the desired point; (5) the milk was placed in the tanks; (6) the speed of revolution was raised to the proper rate; (7) the gate of the first tank was opened wide, and the gate of the second tank was opened sufficiently to maintain a fairly constant level of milk in the first tank; (8) so far as possible a uniform rate of speed was maintained; (9) the cream pail and the skimmed-milk can were removed before the bowl was flushed, unless otherwise noted; (10) after being thoroughly mixed, the cream and the skimmed milk were tested.

TEMPERATURE OF THE MILK

Centrifugal separators work most efficiently when the temperature of the milk is about 85° to 95° F., which is only a few degrees below the body temperature of the cow. Higher temperatures may be used with just as satisfactory results, but they are not often used, especially on the farm; for if the separation is done soon after milking, the temperature could not be better. Lower temperatures seem to make the milk flow more slowly, with a consequent higher percentage of fat in the cream and in the skimmed milk. The report of the studies on temperature is given in tables 1 to 6 inclusive.

It will be noticed that the lowest temperature studied, which was 70° F., caused poor separation as indicated by the tests of the skimmed milk. A further indication that the machine became clogged is that the tests of the cream were low. For this reason the lowest temperature for separation had to be raised five degrees.

The averages for table 1 are not given, since the variations were so great that they would be of little value. It seemed advisable to run another series of determinations in which the speed would be controlled more carefully. In the first determinations the operator, while turning the crank, counted the revolutions six or eight times during the run. Usually the duration of the count was fifteen or thirty seconds; in some cases it was one minute. The time of each run for table 2 was ten or eleven minutes. In the column showing the number of revolutions per minute it is seen that the exact number of revolutions was recorded for from six to nine minutes of each run.

TABLE 1. SEPARATOR 1. EFFECT OF TEMPERATURE ON TESTS FOR FAT IN CREAM AND SKIMMED MILK

Determination	90° F.		80° F.		70° F.	
	Cream test (per cent)	Skimmed milk test (per cent)	Cream test (per cent)	Skimmed milk test (per cent)	Cream test (per cent)	Skimmed milk test (per cent)
1	31.0	.015	34.0	.035	17.5	3.20
2	33.0	.010	44.5	.025	20.0	3.20
3	28.5	.020	33.0	.030	18.0	......
4	34.0	.020	36.0	.020	15.0	2.10
5	24.5	.020	32.0	.030	13.5	3.00
					75° F.	
6	26.0	.025	30.0	.050	36.5	.30
7	31.0	.020	38.5	.040	21.0	1.20
8	34.0	.025	47.0	.030	31.5	.17
9	28.0	.025	33.0	.030	52.0	.04
10	32.5	.020	41.0	.025	35.5	.07
11	31.0	.020	39.0	.030	45.5	.04
12	26.0	.050	36.0	.050	45.0	.08
13	26.5	.040	32.0	.060	36.5	.09
14	27.0	.030	36.0	.040	33.0	.90
15	26.5	.025	33.0	.040	50.0	.07
16	31.0	.020	36.0	.030	44.0	.05
17	27.0	.040	33.0	.030	33.5	.05
18	28.0	.040	32.0	.030	46.0	.08

TABLE 2. SEPARATOR 1. EFFECT OF TEMPERATURE ON TESTS FOR FAT IN CREAM AND SKIMMED MILK

Temperature	Determination	Cream test (per cent)	Skimmed milk test (per cent)	Revolutions of crank per minute
90° F.	1	29.50	.020	61, 60, 61, 60, 60, 60, 60
	2	30.50	.020	60, 61, 60, 60, 60, 60
	3	29.50	.020	60, 60, 60, 59, 60, 60
	4	....	....	....
	Average	29.83	.020	....
80° F.	1	35.50	.030	60, 60, 60, 60, 60, 61, 60, 60
	2	36.50	.040	60, 60, 60, 60, 60, 60, 59
	3	36.00	.035	62, 60, 60, 61, 60, 62, 60, 60
	4	39.00	.050	60, 60, 60, 59, 60, 60, 60
	Average	36.75	.039	....
75° F.	1	43.00	.070	60, 60, 60, 61, 60, 61, 60
	2	39.00	.065	60, 60, 59, 59, 59, 60, 59, 59, 60
	3	45.50	.070	62, 60, 60, 60, 60, 60, 60, 60
	4	45.00	.070	60, 59, 59, 60, 60, 60, 61
	Average	43.12	.069	....

The figures in table 2 are more satisfactory than those in table 1, because the variation from one determination to the next was not large. It is evident that the more uniform results are due to a more uniform

TABLE 3. SEPARATOR 2. EFFECT OF TEMPERATURE ON TESTS FOR FAT IN CREAM AND SKIMMED MILK

Temperature	Determination	Cream test (per cent)	Skimmed milk test (per cent)	Revolutions of crank
90° F.	1	28.0	.050	240 in 4 minutes
	2	28.0	.020	240 in 4 minutes
	3	28.0	.030	240 in 4 minutes
	4	28.0	.040	240 in 4 minutes
	5	28.5	.040	240 in 4 minutes
	Average...	28.1	.036	....
75° F.	1	30.0	.060	416 in 7 minutes
	2	31.0	.050	420 in 7 minutes
	3	31.0	.040	420 in 7 minutes
	4	31.5	.045	420 in 7 minutes
	5	32.5	.055	420 in 7 minutes
	Average...	31.2	.050	....
70° F.	1	39.0	.040	420 in 7 minutes
	2	42.5	.110	420 in 7 minutes
	3	40.0	.270	419 in 7 minutes
	4	36.0	.730	390 in 6½ minutes
	5	40.0	.120	421 in 7 minutes
	Average...	39.5	.254	....

TABLE 4. SEPARATOR 3. EFFECT OF TEMPERATURE ON TESTS FOR FAT IN CREAM AND SKIMMED MILK

Temperature	Determination	Cream test (per cent)	Skimmed milk test (per cent)	Revolutions of crank
90° F.	1	21.0	.035	448 in 10 minutes
	2	21.0	.035	405 in 9 minutes
	3	21.0	.035	404 in 9 minutes
	4	21.0	.025	404 in 9 minutes
	5	21.0	.025	404 in 9 minutes
	Average...	21.0	.031	....
80° F.	1	22.0	.050	406 in 9 minutes
	2	12.5	.055	405 in 9 minutes
	3	20.5	.050	406 in 9 minutes
	4	22.5	.055	405 in 9 minutes
	5	22.0	.055	406 in 9 minutes
	Average...	*21.7	.053	....

* This average does not include determination 2, in which something unaccountable happened.

speed. However, there was a variation, and consequently it was thought best to obtain a still more uniform speed by counting for a longer period, because when the revolutions per minute were counted it was likely that a one-half or a three-fourths turn of the crank might be counted as a full revolution.

The tests showed a higher average percentage of fat in cream and in skimmed milk at the lower temperatures. Greater variation was shown

TABLE 5. SEPARATOR 4. EFFECT OF TEMPERATURE ON TESTS FOR FAT IN CREAM AND SKIMMED MILK

Temperature	Determination	Cream test (per cent)	Skimmed milk test (per cent)	Revolutions of crank
90° F.	1	28.0	.020	495 in 9 minutes
	2	29.5	.020	495 in 9 minutes
	3	30.0	.020	495 in 9 minutes
	4	30.0	.020	495 in 9 minutes
	5	30.0	.020	496 in 9 minutes
	Average...	29.5	.020	....
75° F.	1	31.0	.025	494 in 9 minutes
	2	31.0	.030	495 in 9 minutes
	3	32.0	.020	495 in 9 minutes
	4	30.5	.025	495 in 9 minutes
	5	30.0	.020	495 in 9 minutes
	Average...	30.9	.024	....

TABLE 6. SEPARATOR 5. EFFECT OF TEMPERATURE ON TESTS FOR FAT IN CREAM AND SKIMMED MILK

Temperature	Determination	Cream test (per cent)	Skimmed milk test (per cent)	Revolutions of crank
90° F.	1	28.5	.050	600 in 10 minutes
	2	29.5	.025	600 in 10 minutes
	3	29.0	.050	600 in 10 minutes
	4	29.5	.050	600 in 10 minutes
	5	27.5	.050	600 in 10 minutes
	Average...	28.8	.045	....
80° F.	1	27.0	.060	570 in 9½ minutes
	2	32.0	.060	570 in 9½ minutes
	3	31.5	.040	568 in 9½ minutes
	4	30.5	.050	570 in 9½ minutes
	5	30.0	.050	570 in 9½ minutes
	Average...	30.2	.052	....

in separators 1 and 2 than in any of the other machines. Hunziker[1] gives the reason for this in the following words: "The warmer the milk the more fluid it becomes, and the greater the freedom with which the fat globules can move about. The more fluid the milk the more complete is the separation."

The lower the temperature below 80° or 85° F., the greater is the loss of fat in the skimmed milk. Hunziker adds this sentence to the one just quoted: "75° F. is about the minimum temperature at which most separators will skim closely." The data in these tables show that 70° F. was too low a temperature. In several cases the cream was

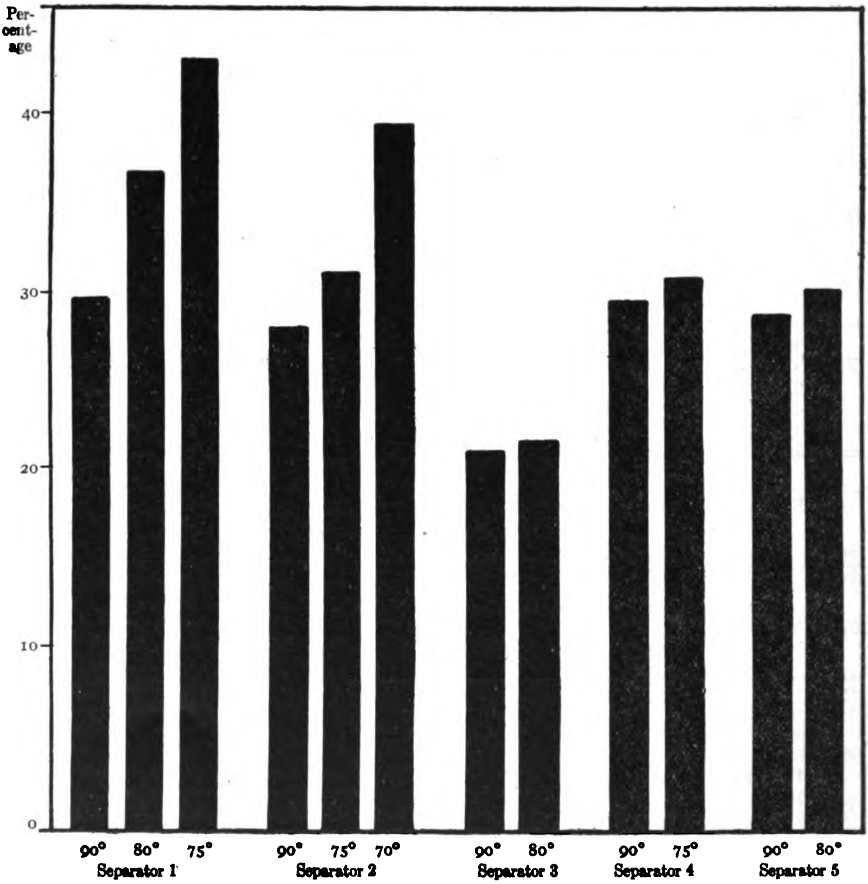

FIG. 117.— *A diagram representing percentage of fat in cream as influenced by the temperature of the whole milk. Temperatures are expressed in degrees Fahrenheit*

[1] Hunziker, O. F. The hand separator and the gravity systems of churning. Purdue Univ. Agr. Exp. Sta. Bul. 116 : 360-361. 1906.

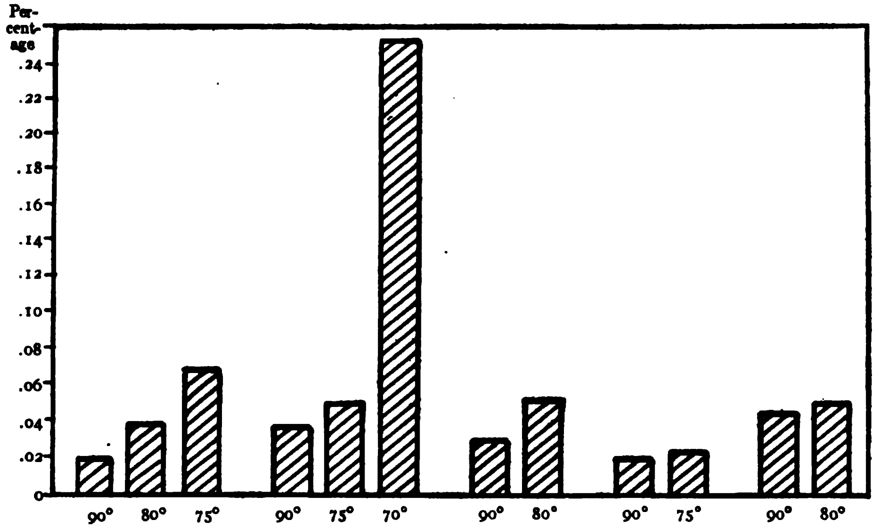

FIG. 118.— *A diagram representing percentage of fat in skimmed milk as influenced by the temperature of the whole milk. Temperatures are expressed in degrees Fahrenheit*

so rich in fat that it clogged the separator, thus closing the passageways, and this resulted in a low-testing cream as noted in the first five determinations in table 1. Hunziker says in a later bulletin[1]: "At 90° to 95° F., the cream contained 21.2 per cent fat. At 50° to 60° F., it contained 33.9 per cent fat." In these experiments a still greater variation was shown on one machine when there was a difference of only fifteen degrees.

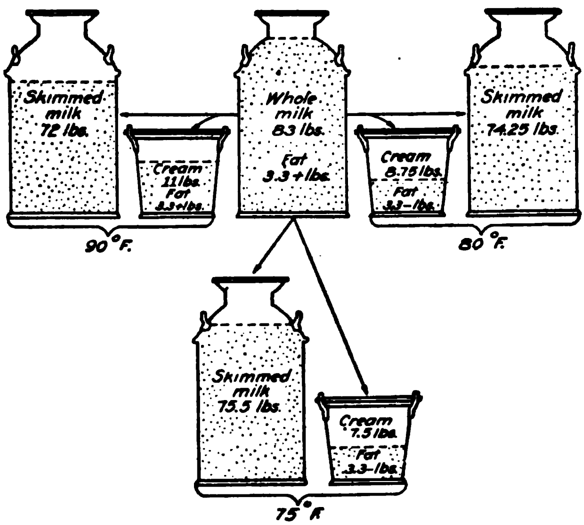

FIG. 119.— *A comparison of the amounts of cream from one can of whole milk separated at different temperatures. The pounds of fat in the whole milk and in each pail of cream are practically the same*

The results of the experiments on temperature are shown graphically in figures 117 and 118. It is apparent that certain types of separators are affected by low temperatures to a

[1] Hunziker, O. F. Why do cream tests vary? Factors affecting richness of cream. Relation of butter-fat to butter. Purdue Univ. Agr. Exp. Sta. Bul. 150 : 44. 1911.

greater extent than are other types. It is also true that there may be a variation in the test caused by the individuality of the machine.

From a study of figure 117, it may be thought that there is an advantage in having the whole milk at a low temperature because the cream from two of the separators contained a much higher percentage of fat than when the temperature was normal. However, the loss of fat in skimmed milk was comparatively greater, as shown in figure 118. When the amount of fat in the skimmed milk does not vary greatly, the amount of cream from a certain quantity of whole milk decreases in direct proportion to the increase of the amount of fat in the cream. This fact is clearly brought out in figure 119. It should be noticed that, as shown in figure 119, the weight of the fat in the whole milk and in all three pails of cream was approximately the same, but that there was a distinct variation in the weight of the cream.

SPEED

It is generally understood that the mechanical separation of the fat and the serum in milk, which differ in specific gravity, is caused by centrifugal force. This force is produced by the rapid revolving of the separator bowl. Naturally, the greater the speed, the greater is the centrifugal force and consequently the more efficient is the separation. In tables 7 to 11 are shown data relative to the effect of various rates of revolution on the percentage of fat in cream and in skimmed milk from different separators. The maximum speed studied in these experiments is that designated on the crank as the proper one.

In the study of the effect of speed, far better results were obtained when the count was made for the entire run or nearly throughout the operation than when it was made for single minutes, because it was difficult to count fractions of turns. When turning for several minutes it was possible to lessen the rate of speed or to increase it, as the occasion might require, in order to have very nearly the proper number of turns at the end of the run.

The speed of the average bowl about four inches in diameter is 9000 revolutions a minute. If the crank is turned sixty times a minute the number of revolutions of the bowl for one turn of the crank is 150. If the operator allows the crank to go only one-half of one turn less than the required speed, the bowl travels 75 turns less than it should. In terms of linear feet, in that one-half turn lost a point on the wall of the bowl has fallen behind about 80 feet. When it is considered that a point on the circumference of a cream separator bowl travels at the rate of nearly two miles a minute, the effect of a slight variation of speed on the centrifugal force, and consequently on the efficiency of skimming, is obvious. Fortunately, the speed of most separators is so rated that

TABLE 7. SEPARATOR 1. EFFECT OF SPEED ON TESTS FOR FAT IN CREAM AND SKIMMED MILK

Determination	About 60 revolutions of crank per minute			About 54 revolutions of crank per minute			About 50 revolutions of crank per minute		
	Actual number of revolutions per minute	Cream test (per cent)	Skimmed milk test (per cent)	Actual number of revolutions per minute	Cream test (per cent)	Skimmed milk test (per cent)	Actual number of revolutions per minute	Cream test (per cent)	Skimmed milk test (per cent)
1......	61, 60, 61, 61, 61, 60, 60....	35.5	.020	50, 52, 53, 53, 54, 54.......	23.0	.030	52, 50, 49, 50, 50, 49, 49, 50, 50..	20.0	.040
2......	61, 61, 61, 61, 60, 60, 60....	33.0	.025	54, 54, 54, 54, 53, 53.......	25.0	.030	50, 50, 49, 49, 49, 50, 50........	20.5	.040
3......	60, 60, 60, 60, 59, 60, 59....	30.0	.025	53, 53, 53, 53, 53, 53, 53....	21.0	.025	52, 50, 48, 50, 50, 48, 50........	21.0	.050
4......	60, 60, 60, 60, 59, 60, 60....	30.0	.020	54, 54, 55, 54, 54..........	23.0	.030	52, 49, 50, 49, 50, 50, 50........	22.0	.040
5......	61, 60, 60, 60, 60, 60, 60....	30.0	.020	55, 54, 54, 54, 54, 54, 53....	23.5	.025	50, 50, 50, 50, 49, 50, 50, 50.....	20.5	.050
6......	60, 60, 60, 60, 59, 60, 60, 60.	30.5	.035	54, 54, 54, 53, 54, 54.......	23.5	.030	446 in 9 minutes = 49.55 per minute....................	22.0	.030
7......	59, 60, 60, 60, 60, 60, 59, 60.	32.5	.025	54, 53, 53, 54, 54, 54, 54....	25.0	.030	299 in 6 minutes = 49.83 per minute....................	22.0	.030
8......	60, 60, 60, 59, 60, 61, 59, 60.	31.0	.020	56, 54, 54, 54, 53, 54.......	25.0	.020	550 in 11 minutes = 50 per minute....................	22.0	.030
9......	59, 60, 60, 60, 60, 60, 60, 60.	29.0	.020	56, 54, 54, 54, 54, 55, 53....	25.0	.040	376 in 7.5 minutes = 50.13 per minute....................	22.0	.035
10......	60, 60, 60, 60, 61, 60, 60....	31.0	.025	54, 54, 53, 53, 54, 54, 53....	22.0	.030	496 in 10 minutes = 49.6 per minute....................	21.5	.035
11......	60, 60, 60, 60, 60, 60, 60....	32.0	.030	54, 53, 54, 54, 54..........	24.5	.040	500 in 10 minutes = 50 per minute....................	21.0	.025
12......	59, 60, 59, 60, 60, 60, 60....	30.0	.030	55, 54, 54, 54, 53, 54, 53....	23.5	.030	500 in 10 minutes = 50 per minute....................	21.5	.030
13......	61, 60, 60, 60, 60, 60, 60....	30.0	.020	53, 54, 53, 53, 54, 54, 53, 54.	23.5	.030	500 in 10 minutes = 50 per minute....................	21.0	.025
14......	59, 60, 59, 60, 60, 61, 60....	28.5	.030	54, 53, 52, 53, 54, 54, 54, 53.	23.0	.030	500 in 10 minutes = 50 per minute....................	21.5	.025
15......	59, 60, 60, 59, 60, 60, 60....	30.0	.020	....	.....	....	500 in 10 minutes = 50 per minute....................	20.5	.025
Average	....	30.9	.024	....	23.6	.030	....	21.3	.034

a drop of eight or ten turns does not cause as much loss of fat in the skimmed milk as might be supposed. Manufacturers are careful not to state a rate of speed for a separator that will give results just above the border line of poor separation. If the instructions given by manufacturers are followed carefully, the separation will be thorough; the fact is, however, that the rate of speed may drop several hundred revolutions of the bowl below the number designated for correct speed, and still the skimmed milk will contain approximately the same percentage of fat as when the bowl is revolving at the so-called normal speed. In the case of hand separators this amounts to five or ten revolutions of the crank less than the number given for normal speed. It is true that the test of the cream is much lower, but this does not mean a loss of fat, for the

TABLE 8. SEPARATOR 2. EFFECT OF SPEED ON TESTS FOR FAT IN CREAM AND SKIMMED MILK

Determination	Revolutions of crank	Cream test (per cent)	Skimmed milk test (per cent)	Revolutions of crank	Cream test (per cent)	Skimmed milk test (per cent)
1........	240 in 4 minutes = 60 per minute	28.0	.050	351 in 7 minutes = 50.14 per minute	28.0	.040
2........	240 in 4 minutes = 60 per minute	28.0	.020	350 in 7 minutes = 50 per minute...	28.0	.030
3........	240 in 4 minutes = 60 per minute	28.0	.030	350 in 7 minutes = 50 per minute...	27.5	.045
4........	240 in 4 minutes = 60 per minute	28.0	.040	351 in 7 minutes = 50.14 per minute	27.0	.040
5........	240 in 4 minutes = 60 per minute	28.5	.040	350 in 7 minutes = 50 per minute...	27.5	.050
Average..	....	28.1	.036	....	27.6	.041

TABLE 9. SEPARATOR 3. EFFECT OF SPEED ON TESTS FOR FAT IN CREAM AND SKIMMED MILK

Determination	Revolutions of crank	Cream test (per cent)	Skimmed milk test (per cent)	Revolutions of crank	Cream test (per cent)	Skimmed milk test (per cent)
1........	448 in 10 minutes = 44.8 per minute....................	21.0	.035	341 in 9 minutes = 37.89 per minute	21.0	.060
2........	405 in 9 minutes = 45 per minute....................	21.0	.035	342 in 9 minutes = 38 per minute..	20.0	.080
3........	404 in 9 minutes = 44.89 per minute....................	21.0	.035	342 in 9 minutes = 38 per minute...	21.0	.070
4........	404 in 9 minutes = 44.89 per minute....................	21.0	.025	342 in 9 minutes = 38 per minute...	21.0	.075
5........	404 in 9 minutes = 44.89 per minute....................	21.5	.035	381 in 10 minutes = 38.1 per minute	21.5	.060
Average..	....	21.1	.033	....	20.9	.069

TABLE 10. SEPARATOR 4. EFFECT OF SPEED ON TESTS FOR FAT IN CREAM AND SKIMMED MILK

Determination	Revolutions of crank	Cream test (per cent)	Skimmed milk test (per cent)	Revolutions of crank	Cream test (per cent)	Skimmed milk test (per cent)
1	495 in 9 minutes = 55 per minute	28.0	.020	405 in 9 minutes = 45 per minute	28.0	.030
2	495 in 9 minutes = 55 per minute	29.5	.020	407 in 9 minutes = 45.22 per minute	28.0	.030
3	495 in 9 minutes = 55 per minute	30.0	.020	361 in 8 minutes = 45.12 per minute	27.3	.030
4	495 in 9 minutes = 55 per minute	30.0	.020	406 in 9 minutes = 45.11 per minute	27.5	.030
5	496 in 9 minutes = 55.11 per minute	30.0	.020	405 in 9 minutes = 45 per minute	27.0	.035
Average		29.5	.020		27.6	.031

TABLE 11. SEPARATOR 5. EFFECT OF SPEED ON TESTS FOR FAT IN CREAM AND SKIMMED MILK

Determination	Revolutions of crank	Cream test (per cent)	Skimmed milk test (per cent)	Revolutions of crank	Cream test (per cent)	Skimmed milk test (per cent)
1	600 in 10 minutes = 60 per minute	28.5	.950	475 in 9½ minutes = 50 per minute	23.0	.060
2	600 in 10 minutes = 60 per minute	29.5	.025	500 in 10 minutes = 50 per minute	23.0	.050
3	600 in 10 minutes = 60 per minute	29.0	.050	500 in 10 minutes = 50 per minute	23.0	.050
4	600 in 10 minutes = 60 per minute	29.5	.050	500 in 10 minutes = 50 per minute	23.0	.040
5	600 in 10 minutes = 60 per minute	27.5	.050	500 in 10 minutes = 50 per minute	23.0	.050
Average		28.8	.045		23.0	.050

amount of cream from a given quantity of milk is proportionately greater. In figure 120 attention is called to the amount of cream that may be obtained from a can of whole milk when separated at different rates of speed. At sixty revolutions of the crank there were 10.75 pounds of cream testing approximately 30.5 per cent fat; at fifty-four revolutions there were 14 pounds of cream testing about 23.5 per cent fat; at fifty revolutions the amount of cream increased to 15.5 pounds and the test dropped to a little over 21 per cent fat.

Hunziker[3] shows the effect of a greater variation of speed. He found that at normal speed the cream tested 44 per cent fat; at about twenty-five turns of the crank less the cream tested 11 per cent fat; and at about twenty-five turns of the crank more the cream tested 63 per cent fat. Naturally,

[3] Hunziker, O. F. Why do cream tests vary? Factors affecting richness of cream. Relation of butter-fat to butter. Purdue Univ. Agr. Exp. Sta. Bul. 150. 1911.

at these more extreme rates of speed there was a greater variation in the tests of the skimmed milk and the consequent greater loss of fat than there was found in these experiments.

The results of the experiments as to the effect of speed are shown graphically in figures 121 and 122. Here, as in the case of the effect of temperature, the influence of individuality of machine or type of separator is very noticeable, either in the percentage of fat in the cream or in the percentage of fat in the skimmed milk.

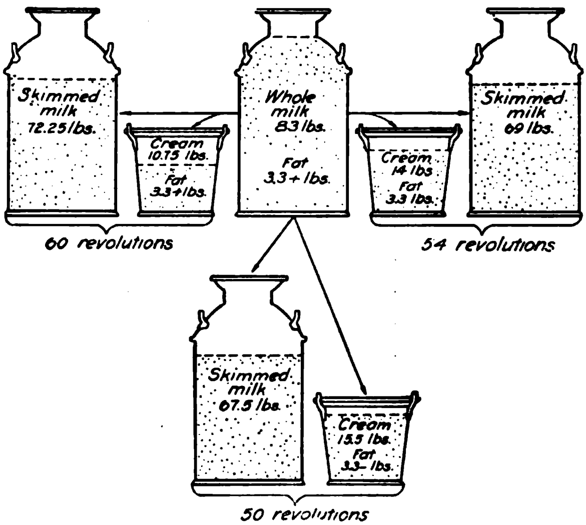

FIG. 120.— *A comparison of the amounts of cream from one can of whole milk separated at different rates of speed. The pounds of fat in the whole milk and in each pail of cream are practically the same*

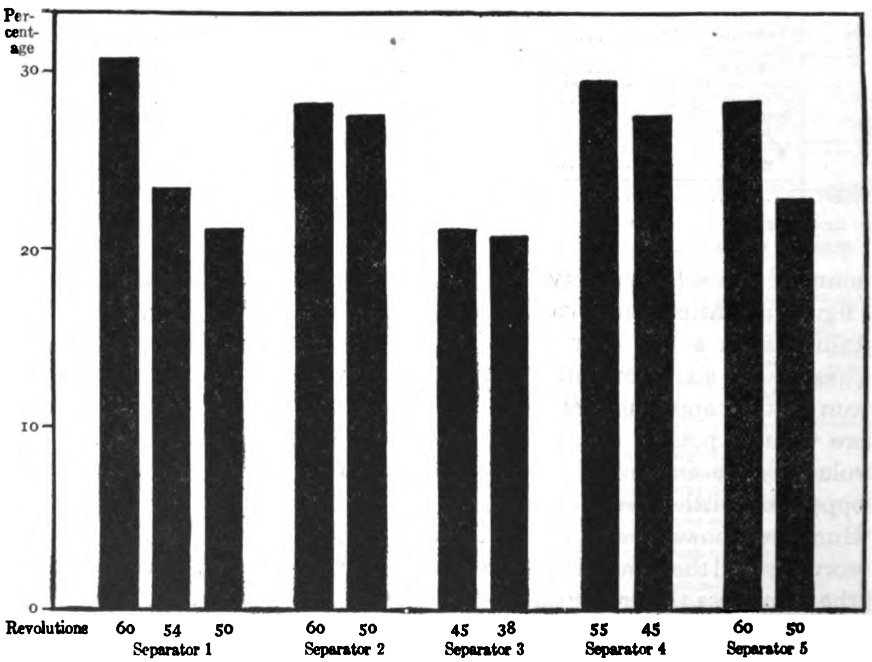

FIG. 121.— *A diagram representing percentage of fat in cream as influenced by the number of revolutions of the separator crank per minute*

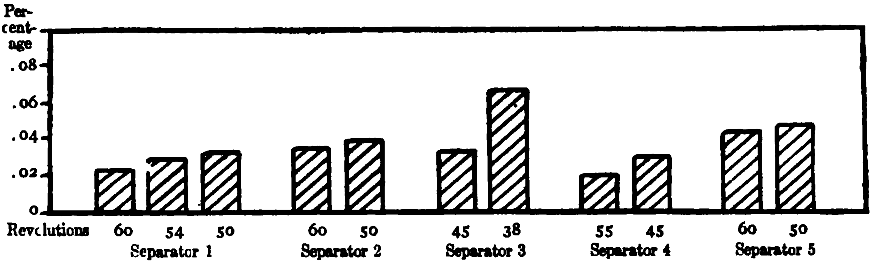

FIG. 122.— *A diagram representing percentage of fat in skimmed milk as influenced by the number of revolutions of the separator crank per minute*

RATE OF INFLOW

The rate of flow of whole milk into the separator bowl is variable even if the separator is supplied with a float — which is a device to regulate the inflow. The results of a study of this factor on separator 1 are recorded in table 12:

TABLE 12. SEPARATOR 1. EFFECT OF RATE OF INFLOW OF THE WHOLE MILK ON TESTS FOR FAT IN CREAM AND SKIMMED MILK

Determination	Tank full		Tank half full		Tank almost empty	
	Cream test (per cent)	Skimmed milk test (per cent)	Cream test (per cent)	Skimmed milk test (per cent)	Cream test (per cent)	Skimmed milk test (per cent)
1..........	25.0	.010	16.0	.015	28.0	.015
2..........	25.5	.020	25.5	.030	26.0	.030
3..........	25.0	.020	21.5	.020	20.0	.030
4..........	25.5	.030	26.5	.020	26.5	.020
5..........	24.5	.030	25.5	.030	26.0	.020
6..........	26.5	.015	28.5	.015	30.0	020
7..........	24.0	.015	26.5	.015	30.5	.020
8..........	25.5	.020	28.0	.020	29.0	.020
9..........	24.0	.015	25.0	.010	29.0	.015
10..........	25.0	.010	25.0	.015	29.0	.020
11..........	28.0	.020	27.5	.020	33.0	.020
12..........	25.0	.020	26.5	.020	30.0	.020
13..........	30.0	.020	23.0	.050	26.5	.020
Average....	25.6	.019	25.0	.021	28.0	.021

The lack of uniformity of the tests from one determination to another is probably due to the variation of speed. It should be noted that the percentage of fat in the cream was practically the same when the tank

was full as when it was only half full, and that when the tank was almost empty there was an increase in the fat. This increase is probably due to the smaller inflow of milk into the bowl. It seems evident that the float regulates the flow with considerable accuracy when the tank has sufficient milk in it to buoy up the float. The percentage of fat in the skimmed milk was not noticeably variable.

PERCENTAGE OF FAT IN WHOLE MILK

The percentage of fat in whole milk is not constant. The milk from a single cow may vary as much as three per cent from one milking to another. Naturally, the variation in the test of the milk from a herd is not so great as in that from the individual cows. The larger the herd, other things being equal, the smaller is the variation. It is true also that the difference in test from day to day is not so great as from milking to milking, and this variation is still less from week to week and from month to month. Tests of herd samples of milk for four consecutive milkings are shown in table 13. It will be noticed that there were from six to fifteen cows in these herds.

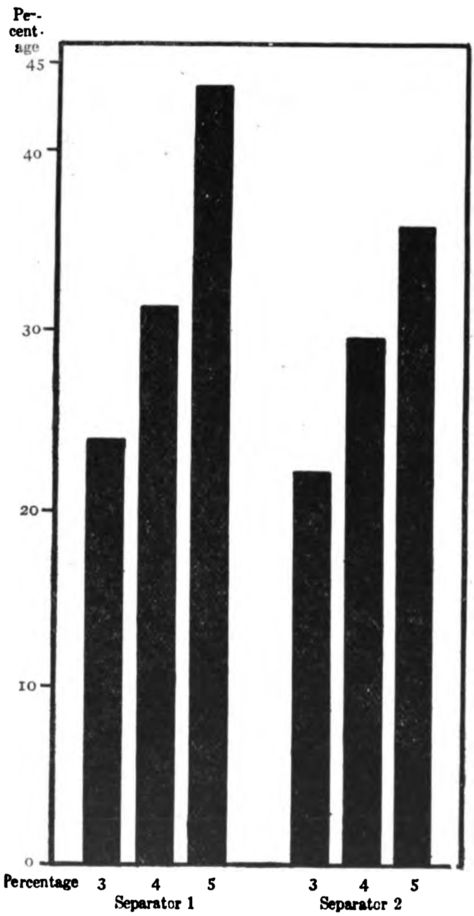

FIG. 123.— *A diagram representing the percentage of fat in cream as influenced by the percentage of fat in whole milk. The figures at the left of the diagram represent percentage of fat in cream, and those underneath represent percentage of fat in whole milk*

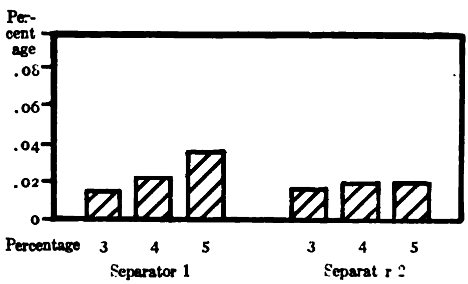

FIG. 124.— *A diagram representing the percentage of fat in skimmed milk as influenced by the percentage of fat in whole milk. The figures at the left of the diagram represent percentage of fat in cream, and those underneath represent percentage of fat in whole milk*

TABLE 13. VARIATION IN TESTS OF HERD MILK FROM ONE MILKING TO ANOTHER

Herd	Number of cows	Percentage of fat in			
		First milking	Second milking	Third milking	Fourth milking
1	15	4.9	4.7	5.2	5.5
2	10	4.4	4.7	4.7	4.3
3	12	3.4	4.5	3.3	4.3
4	14	3.9	3.6	4.3	4.5
5	14	3.2	3.7	3.3	4.1
6	8	4.3	4.8	4.0	4.8
7	8	6.0	6.9	5.2	4.7
8	6	4.4	4.1	4.2	4.1
9	10	3.3	4.3	3.0	3.7

The variations from one milking to the next, as shown in the table, are not great; nevertheless they are important in these studies. The relationship of the test of the whole milk to that of the cream is shown in tables 14 and 15 (page 772).

The results of the experiments of the relation of the percentage of fat in the whole milk to that in the cream are shown in figures 123 and 124. It should be noted that the percentage of fat in the cream is very nearly proportional to that in the whole milk. It seems that the test of the skimmed milk is affected differently by the two types of separators used. In figure 125 it is interesting to note that even though the percentage of fat in the cream is variable, the quantity of cream is almost constant.

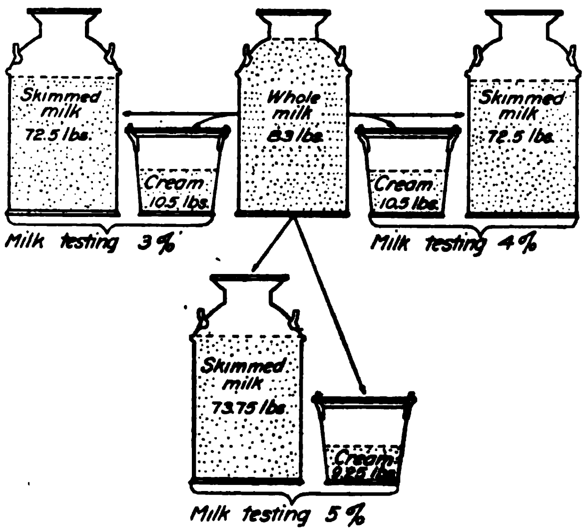

FIG. 125.— *A comparison of the amounts of cream from one can of whole milk containing different percentages of fat. The amount of cream is practically the same for all pails*

TABLE 14. SEPARATOR 1. EFFECT OF DIFFERENT PERCENTAGES OF FAT IN WHOLE MILK, ON TESTS FOR FAT IN CREAM AND SKIMMED MILK

Determination	3 per cent fat in whole milk			4 per cent fat in whole milk			5 per cent fat in whole milk		
	Revolutions of crank	Cream test (per cent)	Skimmed milk test (per cent)	Revolutions of crank	Cream test (per cent)	Skimmed milk test (per cent)	Revolutions of crank	Cream test (per cent)	Skimmed milk test (per cent)
1	61, 60, 60, 60, 60, 60, 61, 60	25.0	.020	61, 60, 61, 61, 60, 61, 60	35.5	.020	60, 61, 60, 60, 60, 61, 60	42.5	.030
2	61, 61, 59, 62, 60, 60, 60, 60, 60	26.0	.020	61, 61, 61, 61, 60, 60, 60	33.0	.025	62, 60, 59, 60, 61, 60, 60	44.0	.040
3	62, 59, 60, 60, 59, 60, 60, 60, 60	24.0	.025	60, 60, 60, 60, 59, 60, 59	30.0	.025	59, 60, 60, 60, 60, 60, 60	45.0	.045
4	61, 60, 60, 60, 60, 60, 60	24.5	.020	60, 60, 60, 60, 59, 60, 60	30.0	.020	60, 60, 60, 60, 60, 60, 60	44.0	.045
5	60, 60, 59, 60, 60, 60, 59, 59	22.0	.015	61, 60, 60, 60, 60, 60, 60	30.0	.020	60, 59, 58, 60, 60, 60, 60, 59	42.0	.050
6	60, 60, 60, 60, 60, 60, 60, 60	24.0	.020	60, 60, 60, 60, 59, 60, 60, 60	30.5	.035	62, 61, 60, 59, 61, 60, 61, 60, 60	43.0	.050
7	60, 59, 60, 60, 60, 60, 60, 60	23.0	.020	59, 60, 60, 60, 60, 60, 59, 60	32.5	.025	61, 59, 60, 61, 60, 60, 61	45.0	.045
8	59, 59, 59, 60, 60, 60, 60, 60	24.0	.015	60, 60, 60, 59, 60, 61, 59, 60	31.0	.020	60, 60, 60, 60, 60, 60, 60	41.5	.030
9	60, 60, 60, 60, 59, 60	24.0	.015	59, 60, 60, 60, 60, 60, 60, 60	29.0	.020	.....	.....	.....
10	60, 58, 60, 58, 60, 60, 59	22.0	.020	60, 60, 60, 60, 61, 60, 60	31.0	.025	.....	.....	.....
Average	.....	23.8	.019	.....	31.2	.023	.....	43.4	.042

TABLE 15. SEPARATOR 4. EFFECT OF DIFFERENT PERCENTAGES OF FAT IN WHOLE MILK, ON TESTS FOR FAT IN CREAM AND SKIMMED MILK

Determination	3 per cent fat in whole milk			4 per cent fat in whole milk			5 per cent fat in whole milk		
	Revolutions of crank	Cream test (per cent)	Skimmed milk test (per cent)	Revolutions of crank	Cream test (per cent)	Skimmed milk test (per cent)	Revolutions of crank	Cream test (per cent)	Skimmed milk test (per cent)
1	495 in 9 minutes	21.0	.020	495 in 9 minutes	28.0	.020	495 in 9 minutes	36.5	.020
2	495 in 9 minutes	22.0	.015	495 in 9 minutes	29.5	.020	496 in 9 minutes	35.0	.025
3	495 in 9 minutes	23.0	.015	495 in 9 minutes	30.0	.020	495 in 9 minutes	35.0	.015
4	496 in 9 minutes	22.5	.020	495 in 9 minutes	30.0	.020	495 in 9 minutes	35.5	.020
5	495 in 9 minutes	22.0	.020	496 in 9 minutes	30.0	.020	495 in 9 minutes	36.0	.020
Average	.....	22.1	.018	.....	29.5	.020	.....	35.6	.020

VARIATION IN THE QUANTITY OF WHOLE MILK, OR IN THE AMOUNT OF LIQUID USED FOR FLUSHING

There is a variation in the quantity of milk from one milking to another, and this causes a variation in the amount to be separated from one time to another. In these experiments one can of milk weighing 83 pounds was considered the average amount for separation, and the variations amounted to 15 pounds less than 83 pounds and 15 pounds more than 83 pounds. In table 16 are shown the results of the study of this factor. These figures indicate that the different quantities of whole milk affect only slightly the percentage of fat in the cream.

Very few persons operating separators use a fixed amount of skimmed milk or of water for flushing the separator bowl. For hand machines two or three quarts of flushing liquid are sufficient. The results of a

TABLE 16. Separator 1. Effect of Different Quantities of Whole Milk on Tests for Fat in Cream and Skimmed Milk

Determination	68 pounds whole milk		83 pounds whole milk		98 pounds whole milk	
	Cream test (per cent)	Skimmed milk test (per cent)	Cream test (per cent)	Skimmed milk test (per cent)	Cream test (per cent)	Skimmed milk test (per cent)
1	26.5	.020	30.0	.020	29.5	.020
2	29.0	.020	29.0	.020	27.0	.020
3	23.0	.030	24.5	.035	28.0	.020
4	24.5	.040	23.0	.030	26.0	.030
5	29.0	.030	29.5	.025	28.5	.025
6	27.0	.025	26.5	.020	28.0	.030
7	27.5	.020	22.0	.020	23.5	.030
Average	26.6	.026	26.3	.024	27.2	.025

TABLE 17. Separator 4. Effect of Different Quantities of Skimmed Milk Used for Flushing the Bowl on Tests for Fat in Cream

Determination	Percentage of fat in cream when bowl is flushed with		
	One quart of skimmed milk	Three quarts of skimmed milk	Five quarts of skimmed milk
1	30.0	28.0	27.0
2	29.0	29.0	27.5
3	29.0	28.5	27.0
4	28.0	28.0	27.0
5	29.0	28.0	27.5
Average	29.0	28.3	27.2

study of this subject are found in table 17. This table shows that the amount of flushing liquid that goes into the cream is only a small proportion of the total, and it affects only slightly the percentage of fat in the cream.

SLIME DEPOSIT

There is always more or less slime deposited on the inside of the separator bowl and on its accessories. When the passages become completely clogged, the machine cannot effect satisfactory separation. The extent of this inefficiency is shown in tables 18 and 19. For the

TABLE 18. SEPARATOR 1. EFFECT OF SLIME DEPOSIT IN THE BOWL ON TESTS FOR FAT IN CREAM AND SKIMMED MILK

Sample	Study 1		Study 2		Study 3	
	Cream test (per cent)	Skimmed milk test (per cent)	Cream test (per cent)	Skimmed milk test (per cent)	Cream test (per cent)	Skimmed milk test (per cent)
1	27.0	.020	27.0	....	27.5	.020
2	28.0	.020	26.5	.015	27.5	.015
3	28.0	.020	29.0	.015	28.0	.015
4	28.0	.020	30.0	.020	31.5	.015
5	30.0	.020	30.0	.020	30.0	.020
6	31.5	.020	31.0	.020	31.0	.020
7	32.0	.020	31.0	.015	31.0	.015
8	....	....	34.0	.015	32.5	.020
Composite	29.0	....	30.0	....	30.0	....

TABLE 19. SEPARATOR 2. EFFECT OF SLIME DEPOSIT IN THE BOWL ON TESTS FOR FAT IN CREAM AND SKIMMED MILK

Sample	Study 1		Study 2		Study 3	
	Cream test (per cent)	Skimmed milk test (per cent)	Cream test (per cent)	Skimmed milk test (per cent)	Cream test (per cent)	Skimmed milk test (per cent)
1	28.0	.050	30.0	.015	25.5	.030
2	28.0	.020	28.0	.015	28.5	.030
3	28.0	.030	29.0	.025	28.0	.040
4	28.0	.040	28.5	.025	26.5	.040
5	28.5	.040	28.5	.030	26.5	.040
6	28.0	.040	29.0	.030	27.0	.045
7	....	....	....	....	27.0	.050

studies shown in table 18, three cans of milk of forty quarts capacity were used and the samples were taken every three minutes. For the studies shown in table 19, four cans of the same size were used and the samples were taken every four minutes.

It appears from the test of the skimmed milk that the separator continues to do efficient work even when a fairly heavy deposit has formed. It is noticeable that the last sample of cream in each study recorded in table 18 tested a little higher than the preceding ones. This is probably due, not to the slime deposit in the bowl, but to the small inflow of whole milk when the tank was nearly empty. The composite samples were taken from the cans at the completion of the entire operation. In the tests recorded in table 19 the percentage of fat in the cream remained fairly constant, but in studies 2 and 3 there was a slight increase in the percentage of fat in the skimmed milk.

SUMMARY

1. The percentage of fat in cream and in skimmed milk from separators 1 and 2 was affected by low temperatures to a greater extent than was that from the other three types of separators.

2. The tests of the cream from separators 1 and 5 were distinctly variable when there was a difference of ten revolutions of the crank per minute. The other separators were not so affected. The variation of ten turns of the crank did not materially affect the percentage of fat in the skimmed milk.

3. There is a slight increase in the test of the cream when the inflow of milk is small.

4. The percentage of fat in cream is in almost direct proportion to that in the whole milk.

5. The variation in the amount of whole milk or of the liquid used for flushing does not cause an appreciable difference in the percentage of fat in the cream.

6. The slime deposit does not materially affect the tests of the cream and the skimmed milk until there is so much that the passages in the bowl become clogged.

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AGRICULTURAL EXPERIMENT STATION OF

THE COLLEGE OF AGRICULTURE

Department of Landscape Art

THE HOME GROUNDS

By E. G. DAVIS and R. W. CURTIS

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The regular bulletins of the Station are sent free on request to residents of New York State.

THE HOME GROUNDS

PART I
ARRANGEMENT OF THE HOME GROUNDS

E. G. Davis

No more varied or more inspiring scenery exists, the world over, than in our own country. With such a beautiful background one would think our city or our country life would necessarily have an ideal environment. But the generosity of nature has in most instances served only to make us wasteful and we have not conserved this scenic wealth. Further, this wealth has tended to make us undervalue beauty in our surroundings, to neither seek to attain it nor carefully preserve it when we are under the necessity of making great changes of grade, erecting buildings, or otherwise altering our surroundings. We destroy fine trees; we desecrate the sacredness of mossy glades; we break old turf and leave bare clay banks; we start to build fine lawns, begrudge ample preparation for them, and then trample their edges and cut them with footpaths.

Residents in a country such as our own, which is in a continually unsettled condition and in some sections is still growing rapidly, are likely not to find time to beautify their surroundings. In many cases, in the haste to locate and erect buildings, to lay out drives and walks, to grade, and in general to attain a settled condition about land newly adapted to present-day use, mistakes are made which later cannot easily be undone.

In the early history of this country much attention was paid to both the arrangement and the beautifying of residences, as the Colonists had but just come from an environment where the beautiful home was the rule rather than the exception. From the cottager to the great landowner, all had their gardens and beautiful surroundings according to their scale of living. The early settler, in starting to search for a new home, necessarily took only his most valued personal belongings; but seeds from the garden that had long been the brightest spot in his life were seldom forgotten. In the struggle that followed for a new nationalism, however, colonial life and all that was a part of it was largely forgotten.

In recent years there has been an awakening of interest in the embellishment of our homes, along with the betterment of the general conditions of our living. We have begun to realize that the dollars we are making are only a means to an end, not the sole object in life. Few of us, however, have come to realize that many of the real pleasures for which we

live do not require dollars or increased incomes. This may apply to the beautiful surroundings of our homes, simple though they may be.

The improvement of home environment is to-day desired and attempted by many persons, perhaps with indifferent success at first. The man of sufficient wealth may seek the professional advice of a landscape architect with the possibility of a greater degree of immediate success. But the face of our country will be changed to a cultivated and beautiful one only when the interest in such matters becomes universal. Homes, lawns, and gardens everywhere, whether they are large or small, whether belonging to the rich or to the poor, all require the touch of the interested individual; with such interest and ensuing effort and enthusiasm, a beautiful result must follow. All art has sprung from such inspired desire and enthusiastic effort; so must come our art of gardening.

Now one may see on every side the evidence of growing and widespreading interest in landscape work, and its possibilities as applied to rural homes as well as to towns and cities. It is the purpose to state in this publication some elemental principles, and to furnish concrete directions that may be of help in rural betterment.

Nothing was ever made beautiful by decoration alone. If the settings of our homes are not pleasing in their bare simplicity, they are little better for any kind of embellishment.

Fundamental to the good appearance of a dooryard is the reasonable arrangement of all that is a part of it. The same principle applies to a farmstead, to a village lot, or to a room in the house; there is a given area, with various essentials to be arranged within it. If there is order within the area its size is apparently greater than if there is disorder. This order consists partly in the placing of the various objects — house, roads, walks, outbuildings, and lawns — in situations suitable for them; and they are not suitably placed if they are not placed with some relation to their use. Therefore the first considerations are of a practical nature.

THE HOUSE

Location

The most important of all objects to be placed on the home grounds is the house. The location of the house largely determines the division of the surrounding land for its various uses. Let us consider, for example, several possible locations for a house on a small area of level ground, as in a village.

A house placed at a reasonable distance from the street and midway between the side boundaries of the lot is shown in diagram in figure 126. The area immediately outside the kitchen belongs to the uses of that part of the house, and may be considered as a cleaning and laundry yard.

If there is a stable or a garage it should be in this vicinity; likewise many of the small outbuildings usual or necessary on a farm. Thus all things pertaining to the useful and necessary management of the home are placed in this area, and therefore it is usually called the service area.

The room in which leisure hours are spent, now called the living room, should command the best parts of the grounds, and good distant views if such are available.

It necessarily follows that the areas outside and in view of the windows of the living room should be of such a nature as to make them easy of

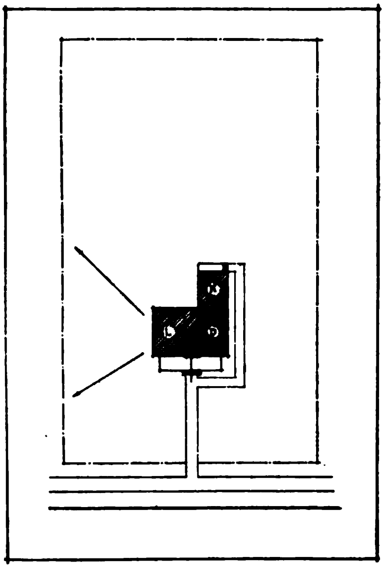


FIG. 126.— *Diagram showing house placed in center of a lot's frontage. D, dining room; K, kitchen; L, living room*

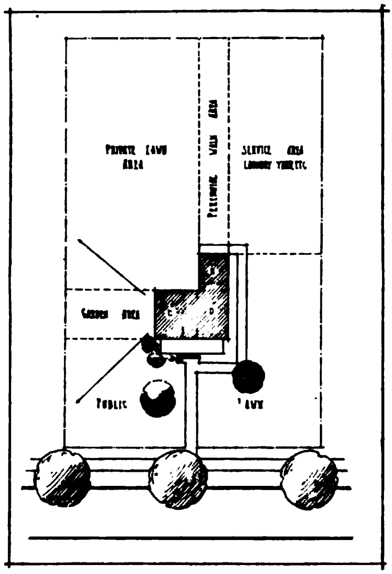


FIG. 127.— *Diagram of a simple landscape development of the ground plan shown in figure 126*

development in lawn and border, and easy of decoration with trees and gardens. Therefore it is evident that the arrangement of the rooms inside the house largely determines the uses of the land outside. A simple landscape development built on the plan offered in figure 126 is illustrated in figure 127.

By a study of this plan it is found that there is more space for a laundry yard and like purposes than is needed, and, on the other hand, the lawns and the gardens are unfortunately restricted; and one cannot but think how much more fortunate a division of land would be possible if the kitchen side of the house were nearer its boundary. A house so placed on

its lot as to give greater expanse of ground from the living room than from the kitchen is shown in figure 128; and from figure 129 it is readily seen that a much better plan may be developed with this location of the house.

In New York, and generally throughout the United States, it may be said that the best prospects from a house are usually toward the southeast, the south, and the southwest. For this reason the best rooms and the pleasure grounds should be toward the south, while the kitchen and the service yards may be placed toward the north.

The area in front of a house and between it and the public road is usually more open and less secluded than the side lawns. This is really

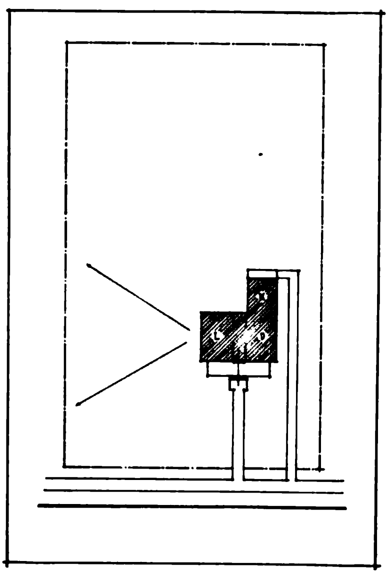


FIG. 128.—*Diagram showing house placed toward side of lot, in order to give greater expanse of ground on living-room side*

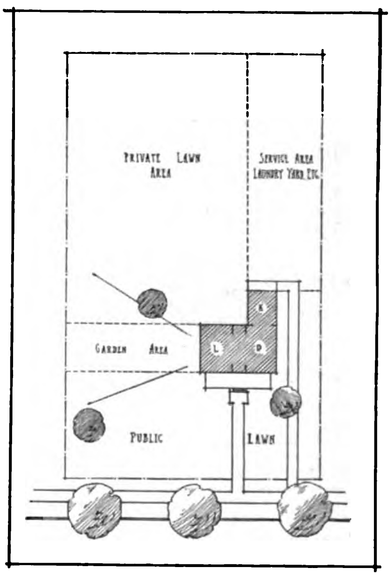


FIG. 129.— *Development of ground plan shown in figure 128*

the setting of the house as seen from the road; therefore this part of the grounds serves mainly as a suitable foreground to the house. Toward whatever point of the compass the outlook of the entrance side of the house happens to be, it does not pay to be too generous with the land in this quarter beyond the amount that is needed to make a good appearance. Referring again to the simple example of a small and comparatively level lot, it can be seen that a desirable relation of the areas in service yard, public lawn, and private lawns and gardens may be retained, no matter toward which point of the compass the house faces. (See figures 130, 131, 132, and 133.)

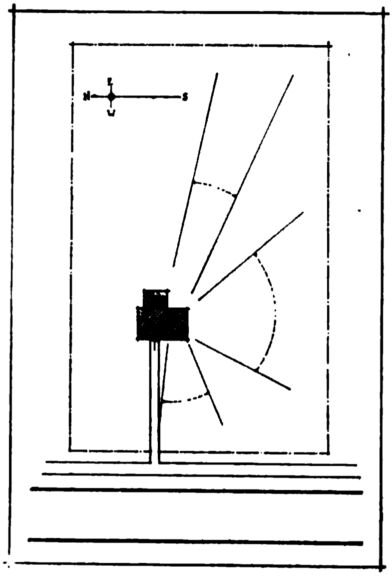


FIG. 130.—*Suggested arrangement when the lot faces west*

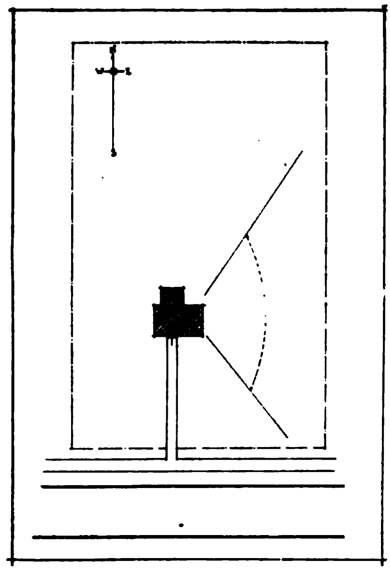


FIG. 131.—*Suggested arrangement when the lot faces south*

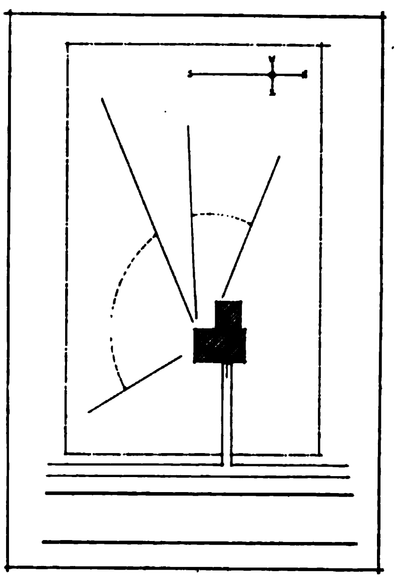


FIG. 132.—*Suggested arrangement when the lot faces east*

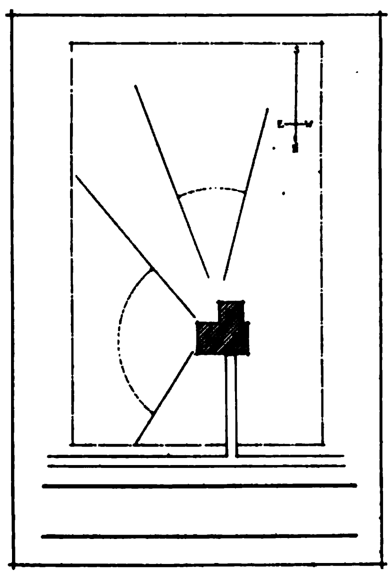


FIG. 133.—*Suggested arrangement when the lot faces north*

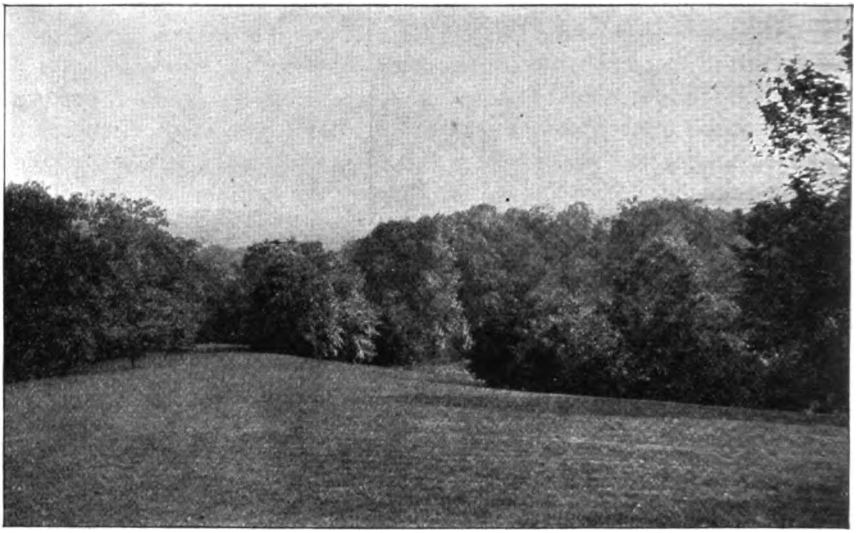


FIG. 134.— *The type of view which suggests that a house should be so faced as to command such an outlook*

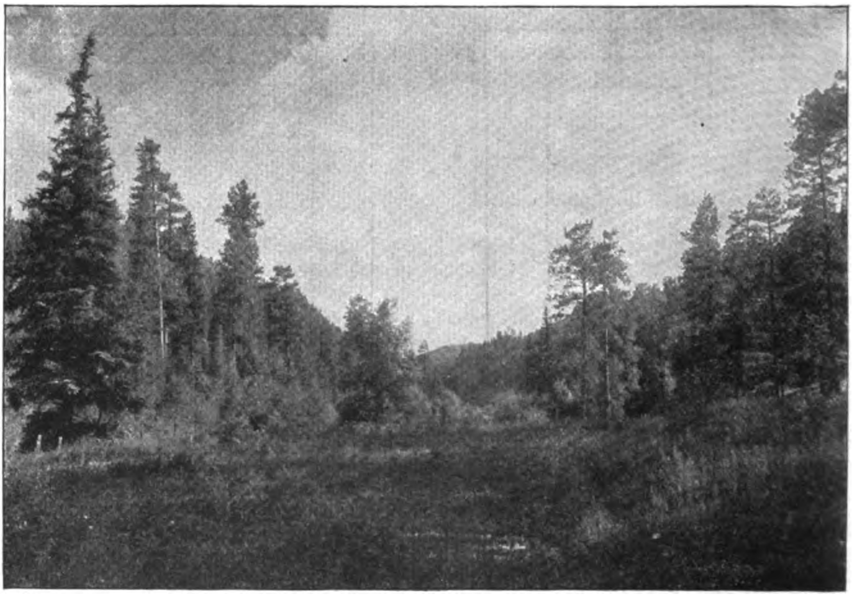


FIG. 135.—*The sort of vista which invites the facing of a house to take advantage of it*

There are other considerations that may affect the placing of a house on a larger property and on land of considerable irregularity in topography. For example, in most cases a house is placed on higher ground than that immediately around it, which permits the house to command the immediate surroundings, while the ground at a distance may either rise or fall without detriment to the outlook. Further, in any choice of site much depends on the availability of good locations for roads and walks, and on the ease and convenience of constructing them. In many cases good views suggest the facing of a house. (See figures 134, 135, and 136.)

While many considerations may bear on the selection of house sites, and while the variety of conditions is as great as the number of different

FIG. 136.— *The kind of outlook which should settle at once the question of placing a house in relation to the view*

properties, in many instances the problems may be solved if they are approached from points of view already set forth.

Type of house

In speaking of houses a good word must be said for the style of cottage that was prevalent fifty years ago, with its low, spreading proportions. Even where the high price of land limits the frontage, as in suburban communities, and forces the building of a narrow house (Fig. 137), there is small justification for such houses; but in the ample room furnished by the open country there is no justification at all for them (Figs. 138 and 139). A comparison of the two types shown in these illustrations is sufficient to convince the reader of the desirable qualities of the house with the more spreading proportions. Happily, there is a tendency to

FIG. 137.—*The narrow house—a bad type*

return to the low proportions in the so-called bungalow of to-day; but that particular style of building was intended for other climates and countries, while the colonial cottage of either brick, stone, or wood was purely a product of local conditions and manners of living (Fig. 138).

The use of masonry is rapidly becoming popular for small houses, and it should supersede less permanent materials. The man who is building for himself, if he wishes to build most permanently and economically, should use masonry in the walls, if not for the floors as well. While the use of either brick, stone, or hollow tile and plaster will add from twenty to twenty-five per cent to the first cost, this will soon be repaid in the saving of upkeep, insurance, and coal bills.

FIG. 138.—*A desirable type of house, with low, spreading proportions*

A new house of fair proportions, but displaying poor architectural detail, is shown in figure 140. It has a fanciful division of window sash into small panes, a poor treatment of dormer windows in the roof, and dark-colored lintels and sills. Worst of all is the poorly disguised imitation of stone in the cement block used. If cement block is desired it should appear as such, not masquerade as something else. As a building

FIG. 139.— *A good colonial type. This is the Davy Burns cottage, which was the oldest building in Washington before it was torn down to make room for the Pan-American Union*

material it is no cheaper than hollow tile, which is said to have many advantages.

FIG. 140.—*A house of fair proportions, but of poor architectural detail*

The main charm of the cottages in small communities of England and Germany is that they are low and snug.

ROADS AND WALKS

Roads and walks mark the lines of daily travel between places most frequented, and are worthy of all the attention that can be bestowed

FIG. 141.— *The line of a road is usually a positive feature in a landscape. This one adds to the picture of which it is a part*

on them. The location of roads must be determined, first, by the points they are to connect, and second, by the grade of the land over which

FIG. 142.— *A box-bordered shady lane on an old Virginia farm*

they are to pass. They should always be graceful in line and reasonably direct. Further, it is desirable that they divide to advantage the land through which they pass. The farmer will not cut across his best fields with his lanes, but will lead the lanes between the fields even if the route is more circuitous. The man who desires to obtain the best appearance in developing his home grounds will not lay out a road which will cut in two what might have been one unbroken sweep of lawn or meadow. Though great values are not always involved in small properties, care should be exercised to preserve their good qualities and to keep them beautiful. The line of a road or a walk is always a conspicuous, and usually a positive, feature in a landscape, adding to or detracting from the scene of which it is a part (Fig. 141).

The first purpose of a walk is use; yet it may also be made

FIG. 143.— *A rustic pergola over a long, straight, b icked walk*

interesting, so that the time required for traversing it may be filled with pleasure (see cover cut). Walks may be made attractive, first of all by their line. If they are short, this line may be straight; but if it is straight the terminals are always in evidence (Fig. 142). These terminals, whether they are barn or shed doors, or doorways to a house, may be made interesting by very simple architectural detail.

FIG. 144.—*Apple trees set close together and trained over at the top to form an arch, or pleached walk*

A walk through an arbor or a trellis, or through a series of arches, has added interest, and persons who use it in inclement weather are protected. (See figures 143 and 144.) Walks of broken or irregular pieces of stone, and with the crevices between them planted with sweet-smelling herbs such as thyme and similar little plants, are at once serviceable and pleasant to traverse. Curved walks may be interesting in the grace of their line and the plantings that skirt them.

OTHER SURROUNDINGS

There is no reason why the areas near house and barn may

FIG. 145.—*Mount Vernon, the home of Washington. Showing the frontage, and the arcade connecting the servants' quarters with the house*

not be attractive. Neatness should be a first consideration, and there should be a purposed, not a haphazard, arrangement. (See figures 145 and 146.) The grounds at Mount Vernon, the home of George Washington, were arranged largely after his own plan; and he prided himself on being a good farmer. They illustrate the value of good arrangement.

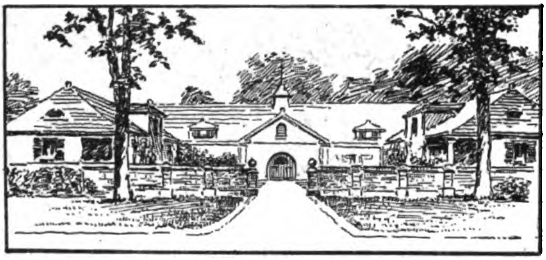


FIG. 146.— *An arrangement of barns and stable yards, with flanking buildings for service quarters*

In the country, and even in the suburb and the village, it may be desirable to set a large part of the grounds about the house with orchard, which may be an attractive feature especially if the orchard is of standard trees. Then the vistas down the rows are invariably interesting. Such a use of land immediately about the house gives the impression of spaciousness to the home grounds without decreasing the income from the land. The orderly rows of trees should not be too close to the building, so as to appear to crowd it, yet the tree rows and their vistas can be attractively related to the outlooks from windows and other vantage points (Fig. 147).

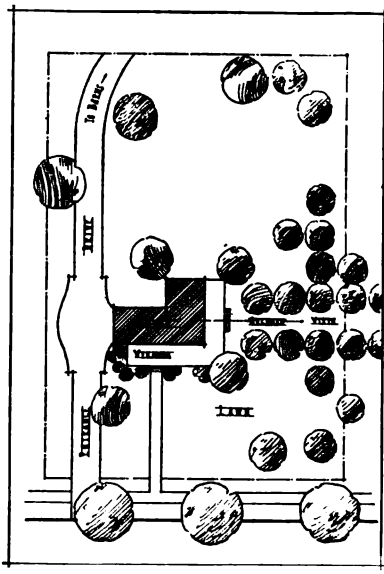


FIG. 147.— *Plan showing the relation of an orchard vista to the outlook from a house*

It is thus evident that one may have interesting and attractive surroundings with only those things that are needed for everyday life. Simplicity in landscape design is largely the result of a fortunate arrangement of merely these essentials — buildings, roads, walks, grass, and trees — and very little other growth. In fact, the best results are attained with nothing individually conspicuous, but with everything in a quiet, harmonious whole, because the beauty of the whole is greater than the beauty of any part (Fig. 148).

Then, too, this beauty without ornament — the great beauty of simplicity — may be brought about by the establishment of order, by the maintenance of neatness, and by tak-

ing care to have all things of good and appropriate character. Additional points, however, need to be considered, and they need not overstep the bounds of strict simplicity.

A house should bear a relation to its surroundings. It has already been shown that walks and roads serve to connect a house with the entrance and with other buildings; that houses should command the land that pertains to them; and that advantage should be taken of far views or of near surroundings. Further, it has been shown that it is a good general rule to keep a house low to the ground — say from one to two feet above it — and if it is already too high, terraces may be raised against it to connect it with the general contour of the ground. (See figure 145.)

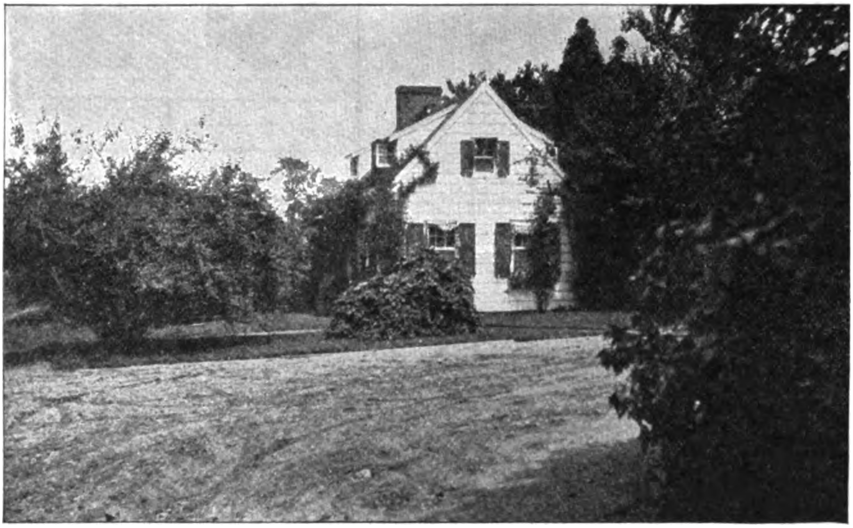


FIG. 148.— *Best results are attained with nothing individually conspicuous. The beauty of the whole is greater than the beauty of any part*

This need not cause dampness in house or cellar. A building should not appear to draw itself up and away from its setting, as though it held it in contempt, nor should a marked difference of level separate and render onerous the free passage to and from a house and the grounds immediately about it.

GRADING AND PLANTING

Many of the problems of making pleasant home surroundings consist of grading and planting, although there is nothing in the prevalent idea that all landscape problems are those of grading and planting. Some errors of plan, however, may be covered by tricks of grading and expedients of planting.

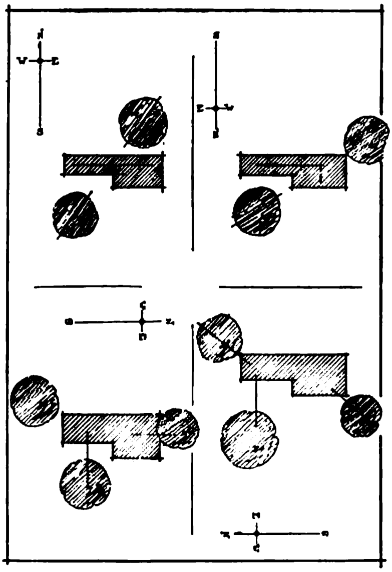


FIG. 149.— *Arrangement of trees for shade, according to the point of compass toward which the house faces*

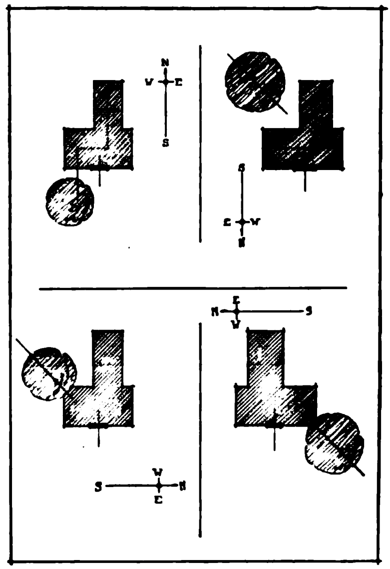


FIG. 150.— *Arrangement of trees for shade, according to the point of compass toward which the house faces*

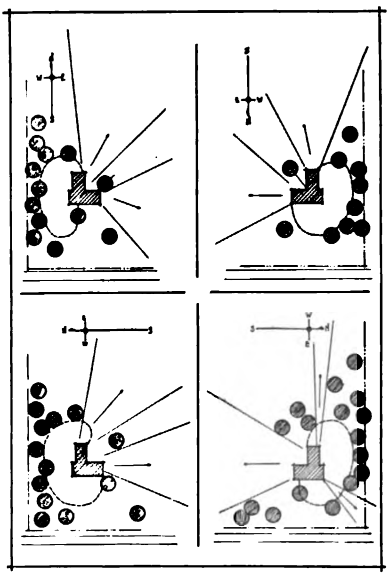


FIG. 151.— *Plans for tree arrangement to afford protection from north winds on lots of different orientation*

As to grading, it may be stated as a general principle that all surfaces immediately about a building should be as smooth, level, and well kept as possible; as the lawns recede from the house, they may become more broken as to surface and less smooth as to turf, until they merge into the natural irregularities of orchard and meadow. In this way the effort required to maintain a lawn may be minimized without injury to the appearance of the whole place. Further, the ground that skirts roads and walks should be apparently level for the width of a few feet, beyond which it may slope up or down. If these slopes are less abrupt at their bases than at their tops they will look better and be more easily maintained.

In planting, one of the first con-

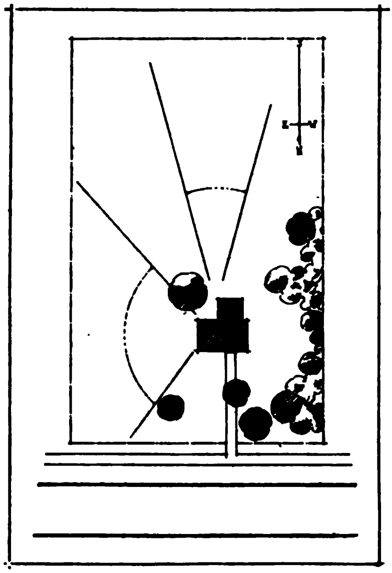


FIG. 152.—*Planting plan to insure best effect of shade, outlook, protection, and privacy on a lot facing north*

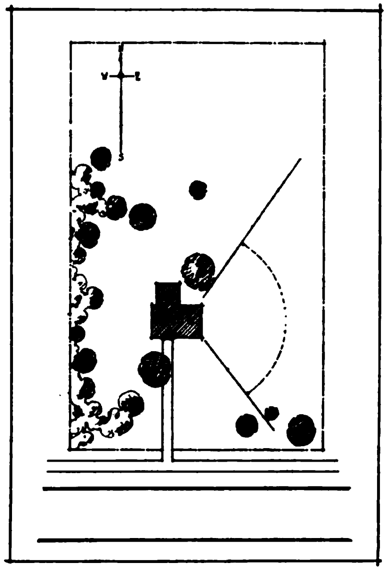


FIG. 153.—*Planting plan to insure best effect of shade, outlook, protection, and privacy on a lot facing south*

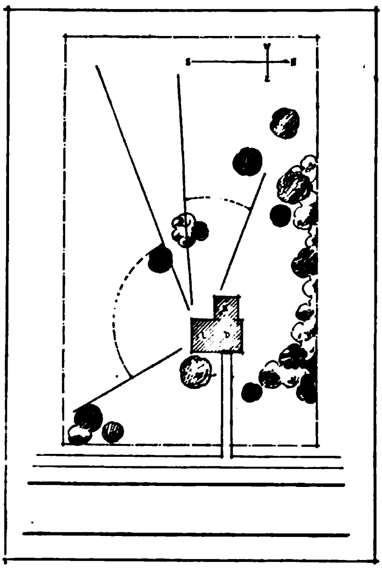


FIG. 154.—*Planting plan to insure best effect of shade, outlook, protection and privacy on a lot facing east*

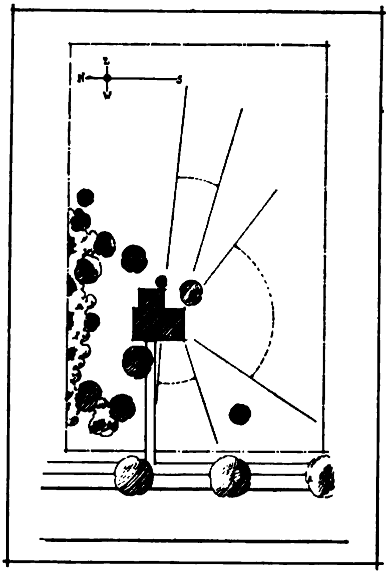


FIG. 155.—*Planting plan to insure best effect of shade, outlook, protection and privacy on a lot facing west*

siderations is that of the placing of individual trees about the house. First, the trees should afford protection, principally from the sun; in addition, however, they should bear a relation to the house, so far as outward appearances are concerned. (See figures 149 and 150.)

In the north, protection from the winter winds becomes a serious consideration. Then, too, privacy, and the prospect from windows or porches, are essential points to be considered in determining the disposition of all the growth about a house. These various considerations are sometimes in conflict, and it then becomes necessary to choose between them. In purchasing land for a home, serious difficulty may be avoided if a site is selected which will lend itself readily to landscape development, whether elaborate or simple. The placing of all planting about the house is based on the ideas expressed in figure 151. These ideas are shown more in detail in figures 152, 153, 154, and 155, which illustrate how any kind of planting should relate to a house facing north, south, east, or west.

IMPROVING THE OUTLOOK

The house and its immediate grounds form the center of the lives and activities of those who use them; regardless of the extent of a property or the character of the surrounding country, those parts in view determine the value of the location. Sightly outlooks should be made available from certain sections of a house, as from its living rooms; unsightly objects in any quarter should be hidden.

In most cases the prospects from all sides of a house are made up of a few spots of interest, a few of undesirable character, and perhaps a large residue of an indefinite or intermediate nature. The question then arises, what is to be done with this third division? The answer may become evident through an examination of a few examples.

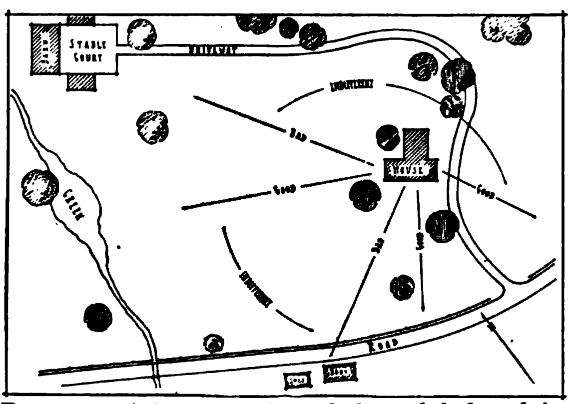


FIG. 156.—*A farmstead with outlooks good, bad, and indifferent*

In figure 156 is shown a farmstead with outlooks of various character, good, bad, and indifferent. This, on first analysis and in its original condition, presents a simple problem. In the following illustration (Fig. 157) may be seen how the arrangement of trees has been planned

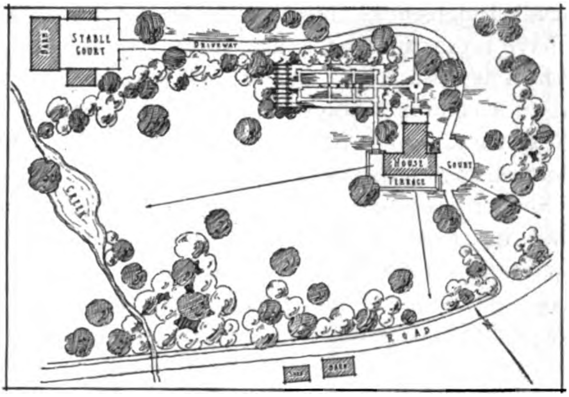


FIG. 157.—*Diagram showing how the farmstead shown in figure 156 may be improved by plantings to accentuate the good outlooks and to hide the bad and indifferent ones*

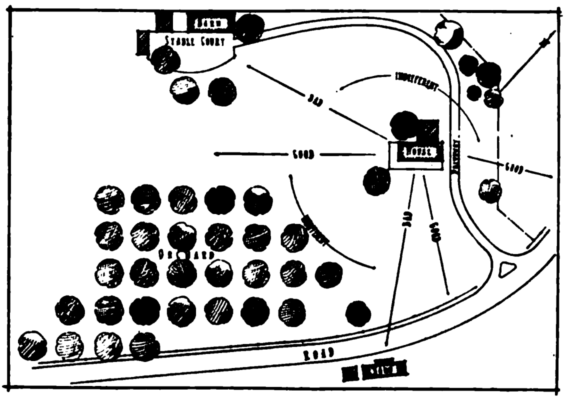


FIG. 158.— *Diagram of farmstead with an orchard which acts as a screen from the road*

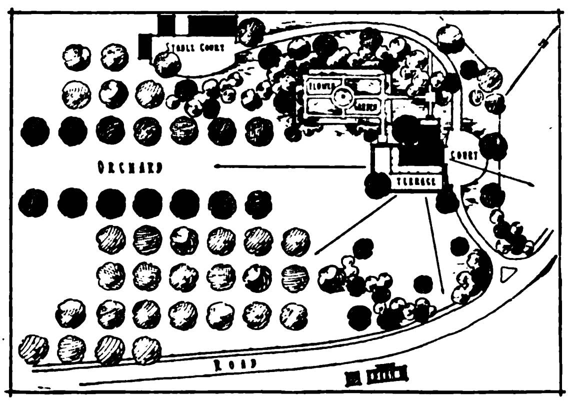


FIG. 159.— *Suggested development of plan shown in figure 158, with good views accentuated and bad views hidden*

so as to hide all disagreeable objects and also to fill those parts of the horizon that have no distinct landscape value. In the first stage in this plan, the horizon is reduced to one or two offscapes, or views off the property, and to a confining border of trees. The grounds have gained inclosure and privacy, which nevertheless add to the apparent extent because an area always appears larger when inclosed than when a part of the open. Shelter has been secured from winter winds, and, in addition, a flower garden has been snugly placed in the northern border of the grounds, where it will neither be in line with the distant views nor interfere with the expanse of the lawns, but will be near to and in view from the house. A few individual trees have been placed about the house and arranged in groups standing out from the more closely set border plantings. The open areas are so clear that they may be used for hay, leaving only so much lawn near to the house as may be easily mowed.

A similar site, where an existing orchard screens the house from the road and takes the place of a mass of border planting, is shown in figure 158. The orchard has been added to as shown in figure 159, in order to narrow the vista over the fields and to use more economically the space near the barn. The planting on the north, which would be largely

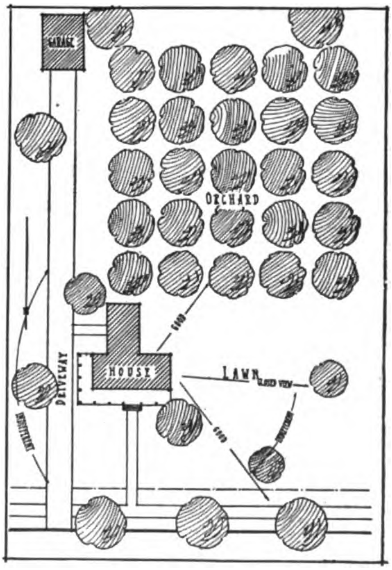


FIG. 160.—*Plan of grounds in a village, showing outlooks of various values*

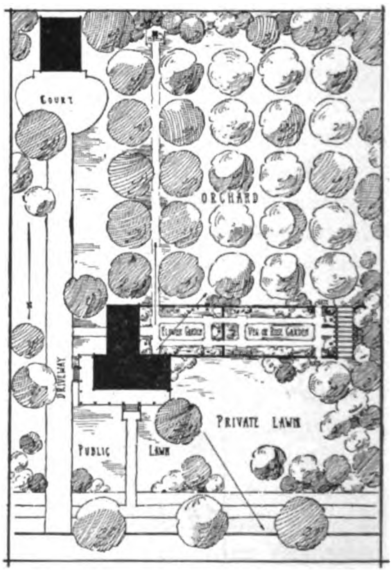


FIG. 161.—*Suggested development of ground plan shown in figure 160*

of trees, is continued in shrubs as it skirts the old orchard near the barn. This effectually blocks the view under the scattered old apple trees and

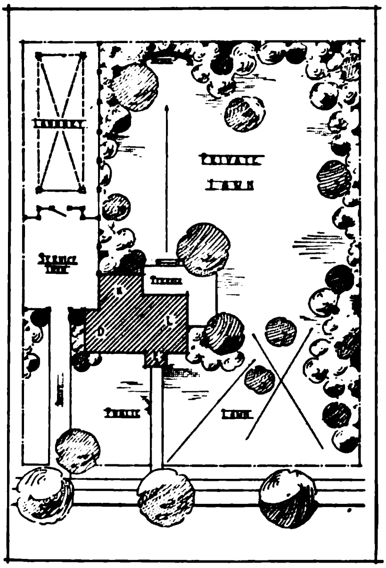


FIG. 162.— *Simple plan for the development of a village or suburban property*

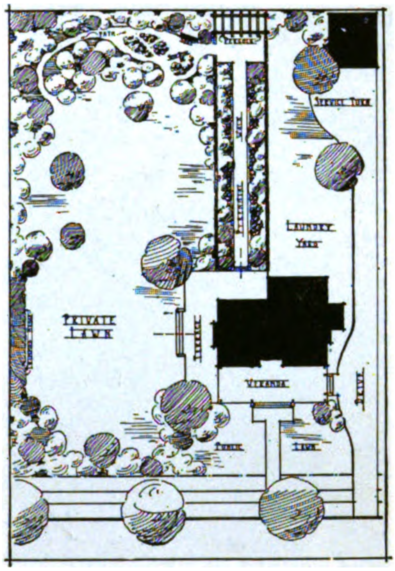


FIG. 163.— *A somewhat more elaborate plan for the development of a village or suburban lot*

hides the stable yard. The same principles are applicable to a house in a small village, as shown in figures 160 and 161.

Other simple treatments of small properties are illustrated in figures 162 and 163. As heretofore stated, it is best to have the greatest expanse

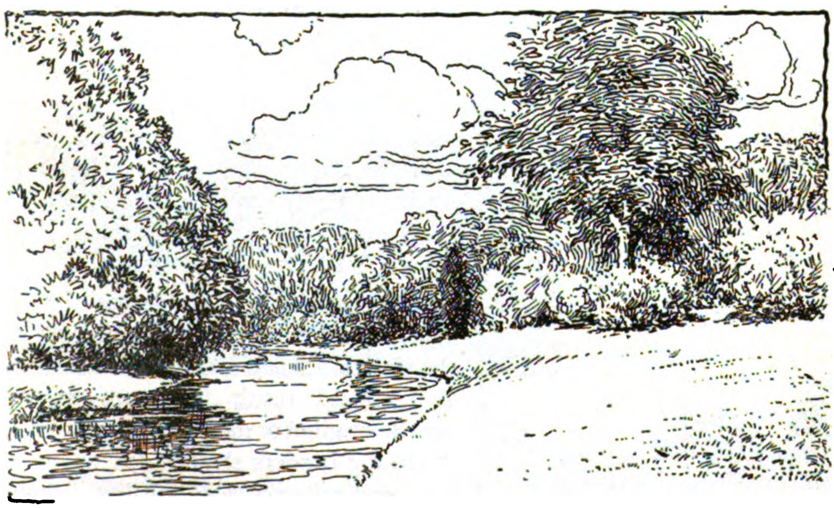


FIG. 164.—*An interesting combination in which the main charm depends on tree forms*

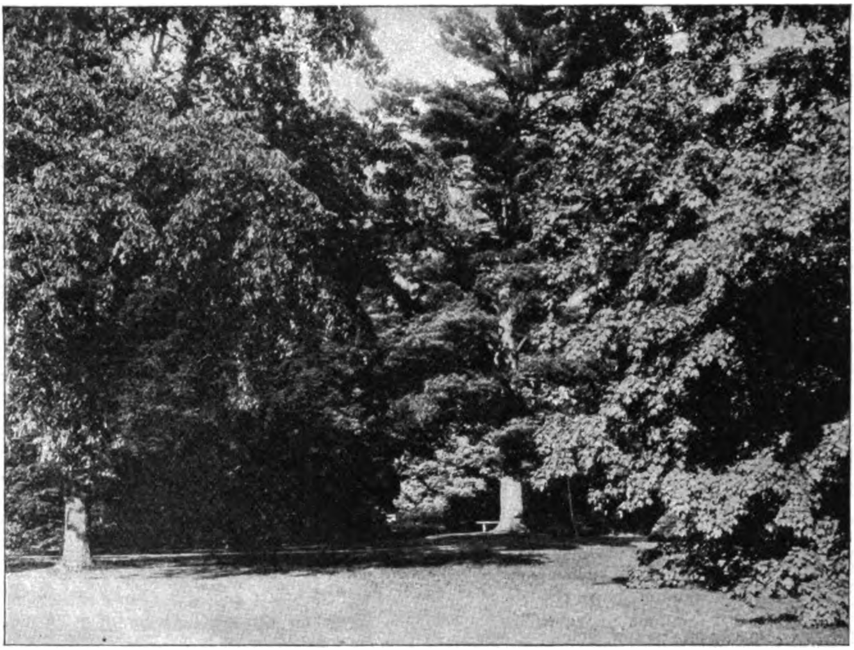


FIG. 165.—*The charm of trees as to light and shade, form and color. Here elm, pine, and maple show variation and harmony*

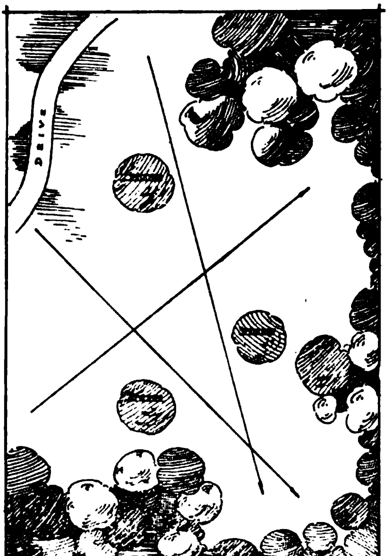


FIG. 166.— *Diagram showing the arrangement of plantings of bays and promontories*

of land outside the living-room windows, and this should be also the sunniest prospect.

It should be evident from the preceding discussion that the location of all plantings is determined after an analysis of existing conditions, and that the plantings should then be made with a definite purpose.

NATURE OF PLANTINGS

It is not sufficient to decide that a place is to have plantings about it. These plantings should have interest, and should result in improvements on the original or natural surroundings. Inclosing borders should not be of a monotonous and rigid outline. Such monotony comes largely from an overuse of shrubs as compared with trees;

a continuous line of this low material gives no relief nor variety. Trees should be used first where there is room for them, and should form the bulk of the plantings. Results of this practice may be seen in the dignified and interesting compositions illustrated in figures 164 and 165. If the line of the border is broken and somewhat loose at the edge, and, further, if outstanding groups and individual trees are judiciously arranged along it, the precise line of the border will be disguised, at least in part of its extent. The shrubs may be placed in the several recesses, or bays, or they may be set on some of the points, or promontories, for special effects, as indicated in figures 134 (page 784) and 166.

FIG. 167.— *The weeping beech forms a mass whose base rests on the ground*

SELECTION OF TREES

Of trees that branch low, or "face themselves down," there is a sufficient assortment: the American beech and the several varieties of the English beech, as well as several of the oaks, maples, and lindens; the small-leaf evergreen trees, as spruces, firs, hemlocks, and some of the pines; and the many kinds of field thorns. From these may be selected trees for plantings of any size. (See figures 167, 168, 169, and 170.) As will be brought out later, a great variety of material in plantings is not desirable. This fact may be evident in some of the foregoing illustrations, but it will be more fully illustrated elsewhere in this bulletin.

FIG. 168.— *Spruces lend themselves best to massed groupings even though their types are spirelike*

It will be remembered that there should be a definite purpose for all that is done in the arrangement of the home grounds, and for this reason the purpose in altering a horizon must

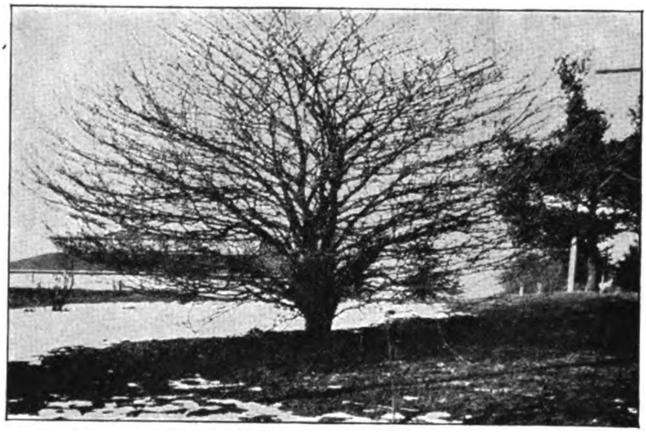


FIG. 169.— *The thorn tree, which has dense, low growth*

be kept closely in mind. Is it the purpose to develop an evenness in this interest all around, or should attention be localized or focused on parts of it? If it is of an equal interest, will not this interest automatically degenerate into monotony? Almost at once definite views will suggest themselves as worthy of special emphasis. There may be lines of walk leading from the doors of the house and forming already prominent lines of sight. At the entrance from the public road there may be a clump of trees; if so, they mark this entrance as an important point in the surrounding green walls. Then, too, in the long plantings that connect the points marked for emphasis, there may be found places at the corners, for example, and possibly elsewhere, that might desirably be differentiated from the growth about them. Further, individual trees and shrubs, sparingly used, may be set out from their

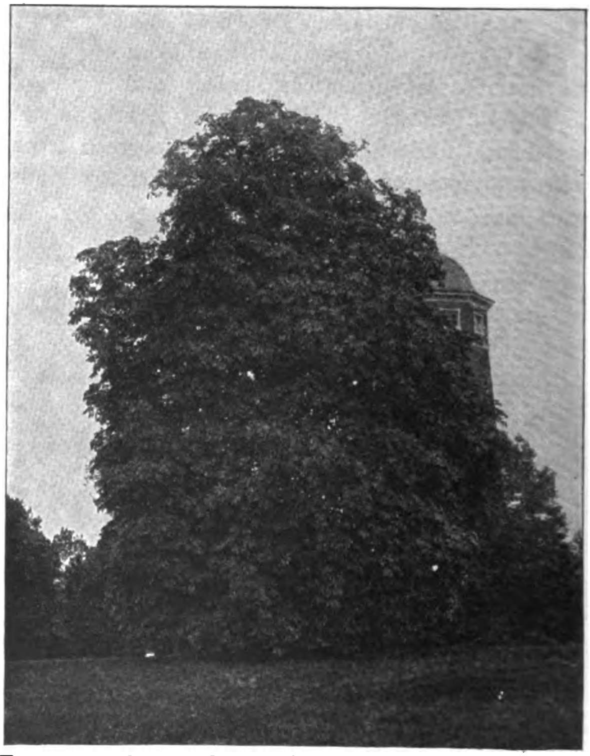


FIG. 170.—*The massed proportions of a specimen horse-chestnut*

backgrounds, but still kept in harmony with them.

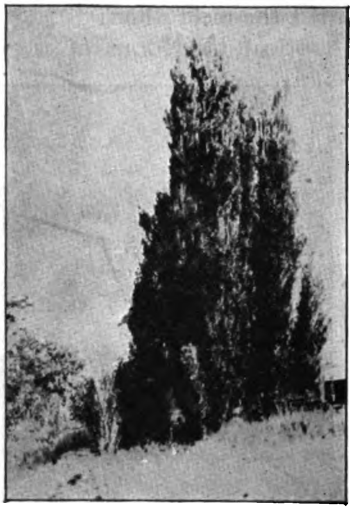


FIG. 171.— *The Lombardy poplar denotes aspiration*

If these focal points in the girdle of greenery should be marked, the next question that arises is how to emphasize them, or, in other words, how to distinguish them from the remainder of the planting. There is nothing so evident in the relative importance of things as superior size, and especially greater height. In outlines against the sky the high points are always the most prominent; and while such high points may be the outlines of large, rounded, massive trees, such masses are not likely to be as strikingly prominent as an individual tree or a clump of trees of a distinctly vertical habit, such as the Lombardy poplar (Fig. 171). This and the pyramidal oak, the fastigiate maple (Fig. 172), and the arbor vitæ, vertical in habit, denote aspiration; the flowering dogwood

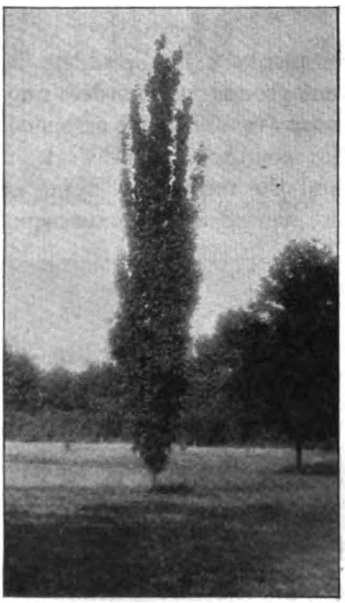


FIG. 172.— *A fastigiate maple. Trees of this type give sharp accents to the sky line*

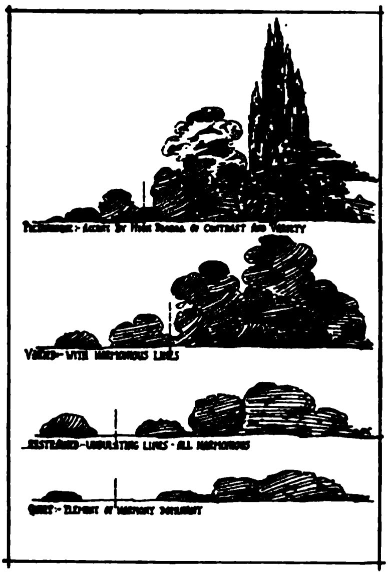


FIG. 173.—*Diagrams of planting borders of various characters—picturesque, varied, restrained, or quiet*

and the field thorn (Fig. 169), which are horizontal, and some of the horticultural forms of weeping trees, such as Wier's cut-leaved maple and the weeping beech (Fig. 167), which are of a graceful and drooping habit, give quite the opposite impression.

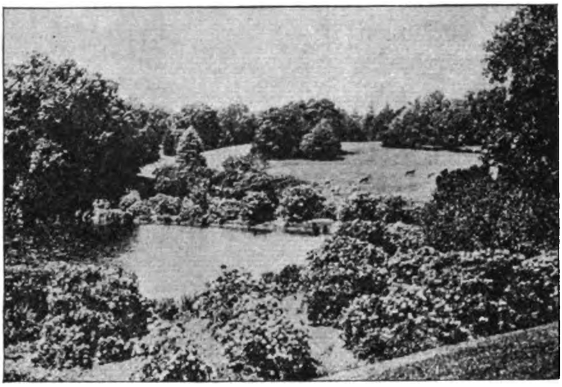


FIG. 174.—*A landscape showing the combined handiwork of nature and of man*

Far the greater number of plant forms, however, are more indefinite in their growth and outline, and these are the ones that make up the larger part of our wood and meadow borders, most of which cannot be improved upon for their quiet, harmonious beauty. Altogether a large variety is available in outline, and in form and habit. Also there is an assortment of trees and shrubs having smaller and larger leaves; and still further variety arises from different shades of green and of the beautiful bronze color of the purple, or copper, beech.

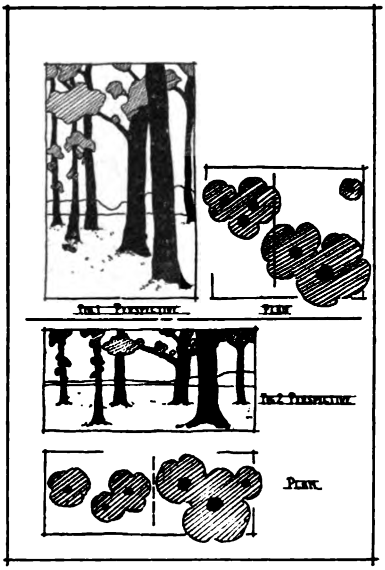
In short, there is contrast and variety in plenty. The problem is, how to use it to the best advantage. Different groups and borders may be made according to the material used and the way in which it is arranged, as shown in figure 173. Illustration of the combined handiwork of nature and of man is shown in figure 174; and the number of types or stages that could be found between the most varied and picturesque, and the most harmonious and quiet, would be infinite.

FIG. 175.—*A simple, well-balanced composition*

KEEPING PLANTINGS IN CHARACTER

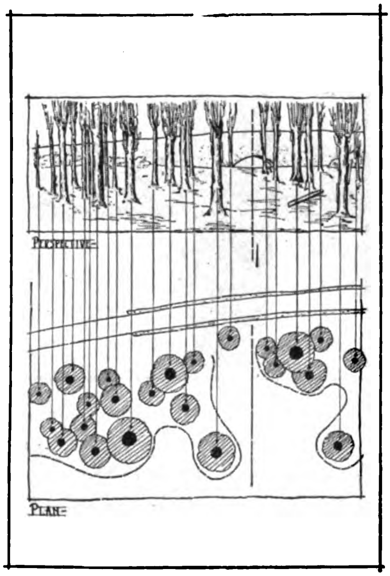
A prospect of quiet character is shown in figure 175, which is reproduced from an old print. While the frame, or flanking mass of trees, is not quite symmetrical in size and outline, the two sides are apparently balanced and are made up of rounded trees which echo the quiet character

of the picture itself. If these flanking masses differed in character from the picture, or if they were not balanced, they would distract attention from the view on which attention should be concentrated. Two pictures made up of the same elements are shown in figure 176; these elements are two groups of trees, a distant sky line, and a foreground. One of these pictures has the vertical proportions dominant, and the other has the horizontal. These groups of trees have been varied in order to adapt them to the spirit of the distant view. An illustration of how an unsightly, long line of an overhead viaduct was made into an interesting



BY COURTESY OF ARTHUR W. DOW

FIG. 176.— *Diagrams of two different pictures made up of the same elements. The upper shows vertical lines, the lower horizontal*



BY COURTESY OF ARTHUR W. DOW

FIG. 177.— *Diagram indicating how vertical lines may be used to relieve monotonous horizontal lines*

picture by contrasting against it a large group of Lombardy poplars is shown in figure 177. Again, an outlook over a rather monotonous country was enlivened by the careful placing of two tall, slender trees almost in the center of the view (Fig. 178). In figure 179 is shown how a walk has been made interesting and its terminal emphasized by the use of trees differing slightly from the adjacent background. This figure shows also how a path through a garden may terminate in a gateway; and the whole picture is kept more within its own precincts and given more unity by the single great tree.

From all this a few definite conclusions may be drawn. If the borders break away for a distinct view, the flanking masses of planting must

be in character with that view. High accents must be used sparingly, and if the view is already good it is good enough as it is and cannot be bettered by a frame, except as that frame is kept subordinate to the picture. If the necessity arises of making an uninteresting picture interest-

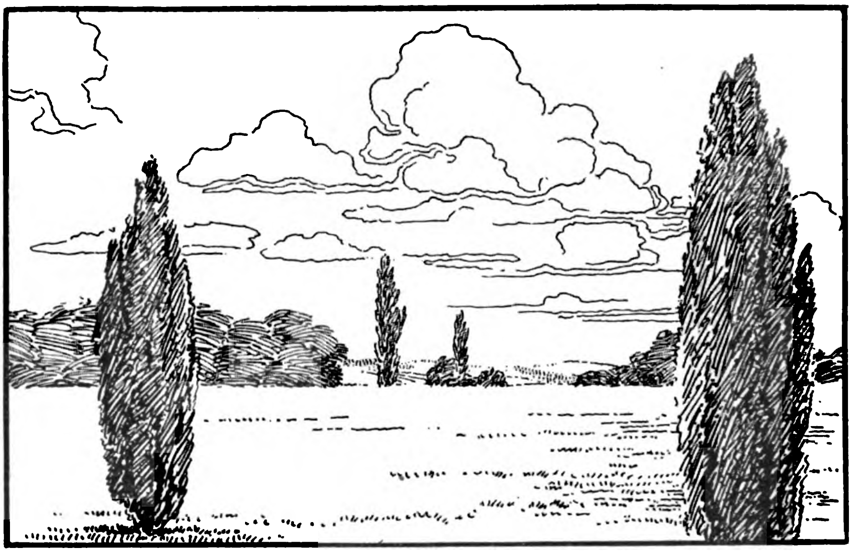


FIG. 178.— *A good picture of simple elements, out of an unpromising outlook, by the use of vertical accents*

ing, it is soon enough to resort to skill in manufacturing fine artificial landscapes. All accent in the interior landscape, or framed picture, should be guarded most carefully, used most sparingly, and reserved for only such points as are already focal by their own importance or have been made so by the planter, who felt it necessary to mark them in this way. Important as these accents are, the long reaches of neutral, harmonious background between are necessary for their complete emphasis. The element of harmony should be dominant in any landscape if it is to be livable, quiet, peaceful, and ultimately pleasing; so that what may have seemed at first to be the most uninteresting parts of the surroundings may be the most necessary.

In the developing of the sky line, or horizon, the greatest prominence should be reserved for one, two, or at the most three, points of greatest importance, and additional prominence may be given to these points by the use of trees of vertical lines. Other less important points may be marked by picturesque groups on a smaller scale, these to be kept either below the sky line of the general background or slightly above it. Outstanding individual trees may be either of the same sort as might

grow naturally in the border, or of some more cultivated variety of the same species, and they may be large or small.

The greatest possible caution should be used with colors other than green, or with fancy foliage. Of the latter, only a few forms, and those of good color, should find a place.

THE USE OF SHRUBS

In general the use of flowering shrubs is mainly restricted to the areas near the house and about the garden. The lawns, if kept in greenery, will then be different from the garden areas, and will also be more quiet, dignified, and restful in character. Shrubs of any kind count more for their foliage than for their flowers, since the flowering period is usually of short duration. If shrubs are used in connection with the lawns they are best arranged in masses of fair size (from five to twenty-five plants), either in recesses of the tree border or on the points of prominence; in this way they may also serve, if it is desirable, for accent in times of flowering. If the whole border is of flowering shrubs it is worse than if there are none, because they then flaunt their monotony.

About the house, planting should be sparingly resorted to, and the individual tree or shrub, especially as it grows older, is far more attractive

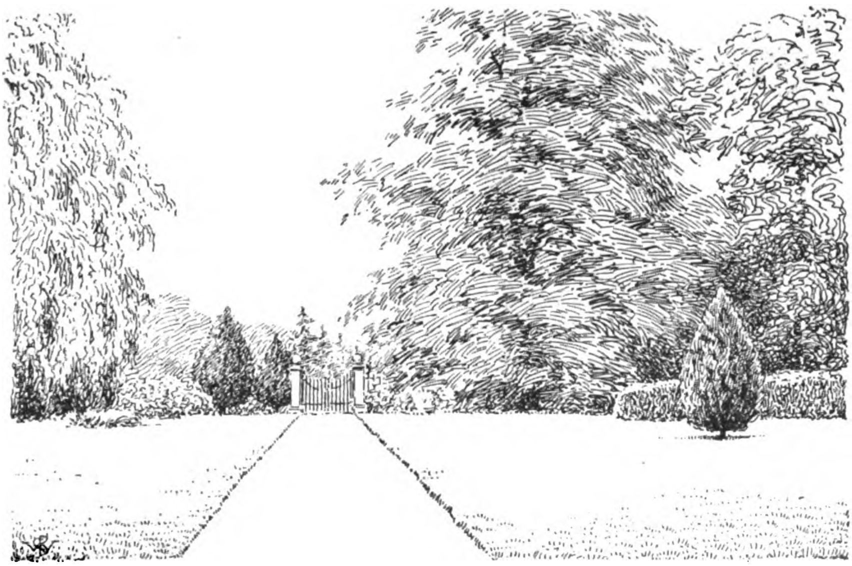


FIG. 179.— *Walk made interesting by trees of special character at its terminal*

than a continuous fringe. The greatest skill lies in the gaining of the best effect with the use of the least material and the least variety of forms.

Individual plants look small when first planted, but room must be allowed for their full development. They will need care in planting and in cultivation for the first few years, but after that they are likely to outgrow one's expectations.

FLOWER GARDENS

And what about flower gardens? At some time in his life every one feels that a flower garden is a necessity. However, until one wants a garden so much as to be willing to care for it and to work in it with his own hands, it is better to do without it. The garden needs the

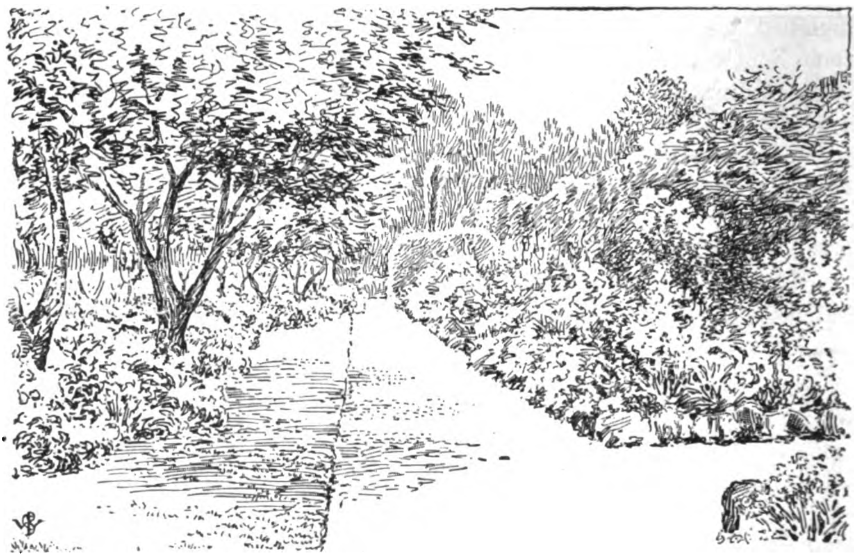


FIG. 180.— *A view from the house windows into an intimate secluded garden*

imprint of an individual hand to make it really interesting, and with this distinguishing mark it will have character even if its plant inhabitants are largely vegetables. A garden may be a perfectly lawless place; it may have in it a great variety of plants as described in Part II; it may have trees, shrubs, roses, annual flowers, perennial flowers, vegetables, fruits, and even weeds — and yet have charm.

The colonists who came from England — where most of the gardens were laid out on geometrical lines — in order to show their independence lined the paths of their gardens in a most irregular fashion, leaving beds of every conceivable odd shape. And yet no one will deny the charm of our colonial gardens, with borders of dwarf box marking the paths and with their high inclosing hedges. These gardens had in them everything of which their owners were fond. Here, rather than on the lawn,

FIG. 181.—*An inclosed and flower-bordered kitchen garden three hundred years old*

is the place for those plant forms in which persons are interested individually and for which they have a particular liking. Above all, a garden should be related to the house (Fig. 180), and so it should be adjacent to the living rooms of a house or in sight from them.

Further, a garden should be inclosed. One should be able to go *into* a garden, and it is not meant to be seen openly from points on the lawn. Yet a glimpse of it is desirable, as an invitation to enter (Fig. 181). Further, the inclosing of gardens, especially from the rough winds, is an essential not to

FIG. 182.—*A glimpse into an English cottage garden three hundred years old. Such topiary effects have to be carefully considered, and usually are out of place and unsuccessful in American gardens*

be ignored if we would there grow even the hardier plants with success and the weak ones at all. Even aside from this practical point of view, a garden that is not inclosed is not a garden at all (Fig. 182).

FIG. 183.— *The dooryard. Here tired man enters; here are the portals of the home*

THE DOORYARD

Although one may not have gardens, or even lawns, or borders, or homelike, quiet, and secluded retreats about the home, yet the doorways and the dooryards should not be forgotten. The entrances to the home should be marked, and should be made cheerful and even beautiful. Here tired man enters; here are the portals of the home; here the stranger is welcomed; and here the friends and neighbors pass in and out. If the doorway does not now have good architectural character, it may have some day. In the meantime, vines, evergreen and others, will flower in spring and summer and will carry foliage through fall and winter; and the most beautiful and the most flowery should be reserved for the doorways (Figs. 183 and 184).

Vines may also be used for decorating the boundary walls, posts, and fences, and for draping the arches of garden walks; but the use of them should be reasonable and they should be placed where they will serve to accentuate ideas already established (Fig. 185).

CONCLUSION

In conclusion, whatever is done with the secluded garden may be kept from the public, if it is bad; but whatever is done about the lawns and in the general arrangement of home grounds becomes a part of them for good or for bad, and not only affects them as a whole but also reflects the taste and character of the owner.

The value of the whole is more important than the value of any part, and a man's house may better be set in a framework that is too simple

FIG. 184.—*A dooryard where the stone steps form a flower garden of rock plants. These steps lead from a terrace to a garden in which native wood plants have been naturalized*

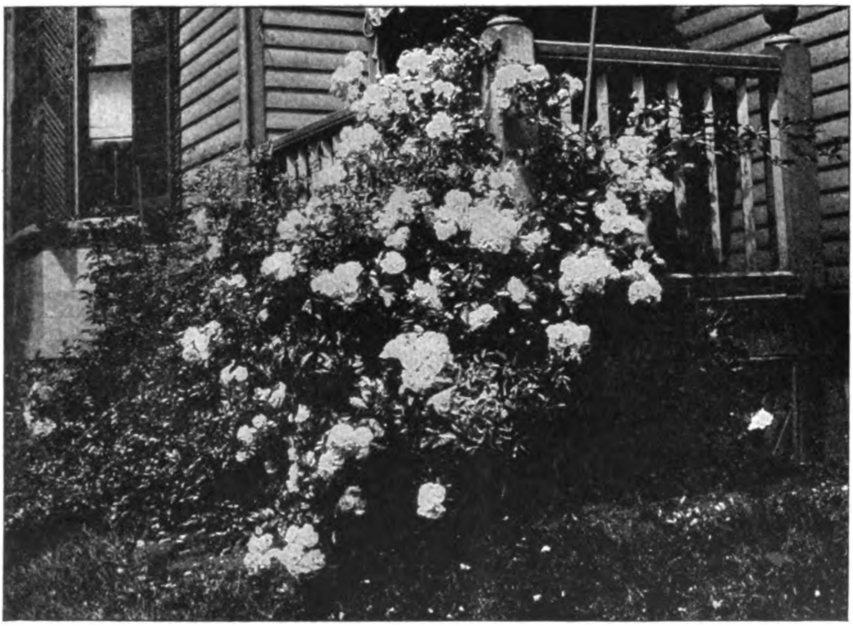


FIG. 185.—*Vines should be used with caution and placed where they will accentuate ideas already established. This vine is a Tausendschön rose on a living-room porch within a few feet of a prize amateur rose garden. It serves to connect the house with the garden*

than in one that is too ornate. And what was said at the beginning of this bulletin is here reiterated — that simplicity should be the aim, and a beautiful simplicity is the most that one may wish for.

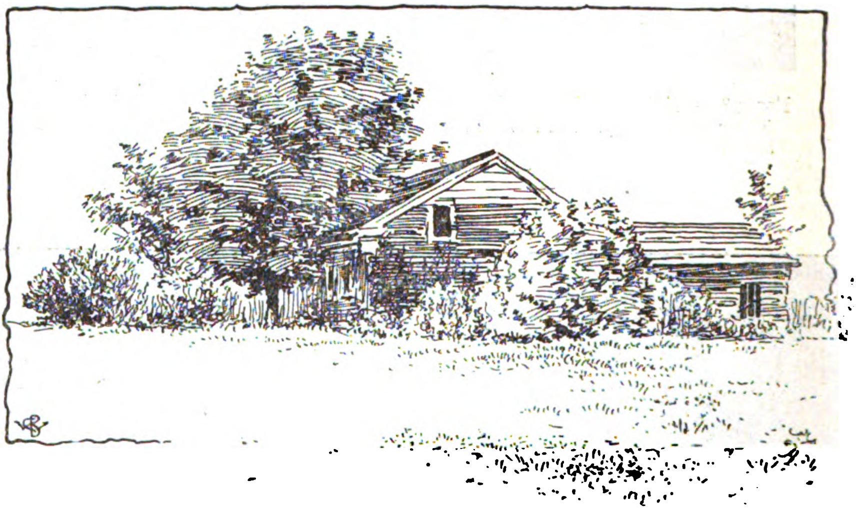


FIG. 186.— *Some one made a good start here and nature did the rest*

PART II

PLANTS FOR THE HOME GROUNDS

R. W. Curtis

The following lists of plant materials are given as an aid in selecting the proper trees, shrubs, and smaller growths suitable for home grounds.[1]

MASS PLANTING, TREES AND SHRUBS

(Natural woodland growth, from 15 to 100 feet. For smaller shrubs, see *Shrubs*, pages 817 to 835)

LARGE (From 50 to 100 feet)

Deciduous.— Sugar Maple (*Acer saccharum*). Red Maple (*Acer rubrum*). American Beech (*Fagus ferruginea*). White Ash (*Fraxinus americana*). Shagbark Hickory (*Carya ovata*). Any of the Oaks (*Quercus alba*, *Q. rubra*, *Q. coccinea*, and others). Basswood, or Linden (*Tilia americana*). Birches (*Betula lenta* and *B. nigra*).

Evergreen.— White Pine (*Pinus strobus*). Red, or Norway, Pine (*Pinus resinosa*). Pitch Pine (*Pinus rigida*). Hemlock (*Tsuga canadensis*).

SMALL (Large shrubs or small trees, from 15 to 30 feet)

Deciduous.— Flowering Dogwood (*Cornus florida*). Thorn (Cratægus). Ironwoods, or Hornbeams (Carpinus and Ostrya). Nannyberry (*Viburnum lentago*). Shadbushes, or Juneberries (*Amelanchier canadensis* and *A. lævis*). Witch-hazel (*Hamamelis virginiana*). Striped Maple (*Acer pennsylvanicum*). Spicebush (*Benzoin æstivale* [=*B. odoriferum*]). Speckled Alder (*Alnus incana*). The last two shrubs are best in wet soil.

Evergreen.— Red Cedar (*Juniperus virginiana*). Arbor Vitæ, or White Cedar (*Thuya occidentalis*).

Note.— These trees cannot live in shade. They grow naturally, in groups, in the open or at the margin of a wood.

SPECIMEN TREES

(Trees of general excellence or with particular traits giving them value as individual specimens)

Formal (Symmetrical and almost round or oval in outline)

LARGE (From 50 to 100 feet)

Deciduous.— Norway Maple (*Acer platanoides*); a tough and hardy tree, low-headed but excellent for the lawn or the average city street where there are no wires. (See *Street Trees*, page 815.) Horse-chestnut (*Æsculus hippocastanum*); should be planted only where there is ample space and moisture. Cucumber Tree (*Magnolia acuminata*). European Beech (*Fagus sylvatica*). European Linden, or Basswood (*Tilia europæa*); blooms from a week to ten days earlier than the American Basswood. White Oak (*Quercus alba*).

Evergreen.— Austrian Pine (*Pinus austriaca*). Swiss Stone Pine (*Pinus cembra*).

SMALL (From 15 to 30 feet)

Deciduous. — Red Buckeye. (*Æsculus carnea* [= *Æs. rubicunda*] var. *briotii*). *Cercidyphyllum japonicum*. *Cornus mas*; bears yellow flowers early in spring, before the leaves appear. Paul's Double Scarlet Thorn (*Cratægus oxyacantha* var. *paulii*); a form of the English Hawthorn. Bechtel's Crab (*Pyrus ioensis* var. *bechtelii*); a double form of the Iowa Crab; the last crab to bloom, and very fine; flowers like small pink roses. Black Haw (*Viburnum prunifolium*). Tree Lilac (*Syringa japonica*); the last lilac to bloom, about July 1; flowers white, in upright clusters.

[1] See Table of Contents, page 891; also, Index of Plants, page 893, for cross reference, pronunciation, and synonymy.

Evergreen.— Swiss Mountain Pine (*Pinus montana*); in the tree, not the shrub (mugho), variety. Red Cedar (*Juniperus virginiana*) and Chinese Juniper (*Juniperus chinensis*), in selected broad round forms; the latter remains green throughout the year, while the former usually browns in winter.

Graceful (More free and restful)

LARGE (From 50 to 100 feet)

Deciduous.— American Elm (*Ulmus americana*). Sugar Maple (*Acer saccharum*). Red Maple (*Acer rubrum*). Oriental Plane Tree (*Platanus orientalis*). Tulip Tree, or Whitewood (*Liriodendron tulipifera*); foliage is rich and glossy, but limbs are very brittle.

Evergreen.— White Pine (*Pinus strobus*). Hemlock (*Tsuga canadensis*).

SMALL (From 15 to 30 feet)

Deciduous.— *Acer ginnala*; a form of the Tartarian Maple, the most brilliant of all Maples in the fall. Flowering Dogwood (*Cornus florida*). Washington Thorn (*Cratægus cordata*). Flowering Crab (*Pyrus floribunda*). Parkman Crab (*Pyrus halliana* [= *P. parkmanii*]). Sorrel Tree, or Tree Andromeda (*Oxydendrum arboreum*); very graceful, with beautiful autumn color.

Evergreen.— *Retinospora obtusa*, *R. pisifera*, and *R. pisifera* var. *plumosa*; beautiful forms of Japanese Cypress.

NOTE.— All Retinosporas in this bulletin belong to the genus Chamæcyparis, but the name *Retinospora* is the more common in commercial use.

Picturesque (More interesting and striking in form, line, or color)

LARGE (From 50 to 100 feet)

Deciduous.— Red Oak and Black Oak (*Quercus rubra* and *Q. velutina*); strong and rugged. Shagbark Hickory (*Carya ovata*); crooked and irregular framework in winter. Sour Gum, or Tupelo (*Nyssa sylvatica*); peculiar horizontal, and even drooping, branches; the most picturesque of any native tree in winter; the best location is near water. Weeping European Beech (*Fagus sylvatica* var. *pendula*); purple varieties, erect and weeping, are more striking, but the normal green-foliage types are more satisfactory. Red, or River, Birch (*Betula nigra*); the curling, reddish brown bark makes the trunk and the limbs of this species very attractive in winter; a clump of River Birch is always a welcome sight; moreover, it seems to be little injured by the bronze birch borer, which renders practically all other birches undesirable for planting. Trembling Aspen (*Populus tremuloides*); usually a small tree, from 40 to 50 feet high, with gray-green trunk and limbs, most attractive against a dark background. Weeping Silver Linden (*Tilia petiolaris*); usually from 40 to 50 feet high.

Evergreen.— Scotch Pine (*Pinus sylvestris*); irregular spreading habit, and bluish green foliage with salmon-colored trunks; grows rapidly but is short-lived in America. Red, or Norway, Pine (*Pinus resinosa*); a native pine, little used but very handsome and thoroughly satisfactory; foliage long and dark green, in heavy clusters, making a strong, bold effect when the trees are massed in groups. Western Yellow Pine (*Pinus ponderosa*); a hardy pine from the West; has much the same effect as, or even a stronger effect than, the Red Pine. Pitch Pine (*Pinus rigida*); a native pine, becoming very picturesque when old; does well under dry, hard conditions.

SMALL (From 15 to 30 feet)

Deciduous.— Cockspur Thorn (*Cratægus crus-galli*); has distinct, horizontal, wide-spreading branches. Weeping Japanese Cherry (*Prunus pendula*); pale rose-purple flowers, appearing early, before the leaves. Oleaster (*Elæagnus angustifolia*); has silvery twigs and foliage. Alternate-leaved Dogwood (*Cornus alternifolia*); a slender little native tree or large shrub, with branches in whorls wide apart, very Japanese-like.

Evergreen.—Jack Pine (*Pinus banksiana* [= *P. divaricata*]); the northernmost pine; somewhat resembling Pitch Pine, but smaller and more spreading and irregular; the best pine for dry, sandy soil. Weeping Hemlock (*Tsuga canadensis* var. *pendula*); very desirable. Weeping Japanese Cypress (*Retinospora pisifera* var. *filifera*). *Retinospora pisifera* var. *squarrosa*, a Japanese Cypress with blue-gray, feathery foliage.

Conical or Vertical Trees for Emphasis

Conical

Deciduous.— Larch (*Larix europæa*). Cucumber Tree (*Magnolia acuminata*). Maidenhair Tree (*Ginkgo biloba*); this remains narrow for forty or fifty years, and then broadens out, with wide-reaching limbs. Pin Oak (*Quercus palustris*); this is the best of the deciduous conical type. (See under *Street Trees*, page 816.)

Evergreen.—

LARGE (From 50 to 100 feet)

Spruces

Norway Spruce (*Picea excelsa*). Probably the most commonly planted conical evergreen. It is hardy and vigorous in most parts of the State for forty or fifty years, after which it begins to die at the top. It is too somber and funereal for specimen planting, and is much better in hedges or windbreaks or for solid screen planting.

Colorado Blue Spruce (*Picea pungens* [=*P. parryana*]). Foliage very stiff and sharp, color ranging from blue to green; Koster's Blue Spruce is the bluest form. In addition to emphatic form, this spruce has very emphatic color, and moreover it is not long-lived. If emphasis of this kind is desired, Silver Fir (*Abies concolor*) should be used. (See under *Firs*.)

White Spruce (*Picea canadensis* [= *P. alba*]). Foliage gray-green, sometimes resembling forms of the Blue Spruce at a distance but never as stiff or as sharply pointed as the latter. It is the best of the native spruces, but *Picea engelmannii*, from Colorado, which is intermediate between *P. pungens* and *P. canadensis*, is better and longer-lived than either.

Oriental Spruce (*Picea orientalis*). Foliage dark, glossy green, the shortest and bluntest of all spruce foliage. This is a handsome tree of fine color and graceful habit, but, like the native Red Spruce (*P. rubra*), it is a very slow-growing tree in cultivation.

Firs

Silver Fir (*Abies concolor*). The best of the firs. Foliage blue-green to blue-gray. A wonderfully beautiful tree, long-lived and thoroughly successful in the East. It is much more satisfactory than any kind of Blue Spruce, but, like the latter, it is very emphatic both in form and color, and one or two on one place should be enough.

Nordmann's Fir (*Abies nordmanniana*). The best fir for dark, glossy green foliage. It is not quite so hardy as the Silver Fir, the foliage sometimes burning on young plants.

Fraser's Fir (*Abies fraseri*). The foliage is finer than that of the northern Balsam Fir, and the tree seems to grow better in cultivation; but neither of these species is as desirable for specimen planting as the two firs named above.

SMALL (From 20 to 30 feet)

NOTE.— All are slow-growing, but may reach a height of from 50 to 60 feet.

Red Cedar (*Juniperus virginiana*), Chinese Cedar (*Juniperus chinensis*), and both the native Arbor Vitæ, or White Cedar (*Thuya occidentalis*), and the Oriental Arbor Vitæ (*Thuya orientalis*). Both the Chinese Cedar and the Oriental Arbor Vitæ are handsomer than the native forms. Umbrella Pine (*Sciadopytis verticillata*). A hardy but rare plant, conspicuous in both form and foliage. The leaves are clustered twenty to thirty in a whorl, are long and narrow, and are dark glossy green in color.

These conical evergreen types are always emphatic and conspicuous, and do not harmonize readily with normal surroundings in America. As specimens such evergreens should be used sparingly. They are much safer in solid groups. Even when planted in mass, the individuals themselves are so emphatic that it takes years for them to merge together into a solid evergreen mass. Comparing a solid planting of Norway Spruce (*Picea excelsa*) with a similar planting of Hemlock (*Tsuga canadensis*), it is seen that in the former every individual spruce is stiff and conical and remains so for years, while in the latter, even five years after planting, the hemlocks, with their graceful habit and foliage, have lost their individuality and merged into one indefinite mass. ***The hemlock is the finest tree that can be used for solid evergreen planting.***

Of large conical evergreens the best is Douglas Fir (*Pseudotsuga taxifolia* [=*P. douglasii*]), called Douglas Spruce or Oregon Pine in the West. This is a vigorous grower of graceful habit, with soft, flexible foliage, and is green or gray-green in color. In buying this, one should be sure to get the Rocky Mountain form. The Coastal Plain form is not hardy in the East.

Vertical

Deciduous

LARGE (From 50 to 100 feet)

Lombardy Poplar (*Populus nigra* var. *italica*). (See *Rapid-growing Trees*, below.) Bolle's Poplar (*Populus alba* var. *bolleana*). This is a narrow, upright form of the European White Poplar (*P. alba*), and is just as weak-wooded and undesirable. (See *Rapid-growing Trees*, below.) Moreover, the white woolly coating on the undersides of the leaves makes the tree very conspicuous, and when conspicuous color is added to narrow, upright form the tree becomes too emphatic for ordinary use. The Lombardy Poplar, with its normal green foliage, is a much safer material to use when vertical emphasis is needed. Upright Sugar Maple (*Acer saccharum* var. *monumentale*); this is a new and very desirable form; narrow and upright.

SMALL (To 30 feet)

Pyramidal English Oak (*Quercus pedunculata* var. *fastigata*); small and short-lived.

Evergreen.— (These are small trees, usually from 20 to 30 feet high, but may reach a height of from 50 to 60 feet. All are slow-growing.) Red Cedar (*Juniperus virginiana*). Arbor Vitæ, or White Cedar (*Thuya occidentalis*). Irish Juniper (*Juniperus communis* var. *hibernica*), from 15 to 20 feet high.

RAPID-GROWING TREES

Poplars, Willows, Birches, Soft Maple, Ailanthus, and Wild Black Cherry (*Prunus serotina*)

As a class, the rapid-growing trees are weak-wooded and transient. They are cheap, and are usually thought of as fillers for temporary or quick effects. The Cherry is the most durable of the lot, and the Ailanthus and the Soft Maple are next in order. The Ailanthus is the best of all trees for withstanding the smoke and dust of a dry city tenement district.

The Cottonwood (*Populus deltoides*) is the strongest, most enduring, and most spreading and oak-like, of all the Poplars. The Carolina Poplar is nearly related to it, but is more upright, rapid, and vigorous. The Lombardy Poplar is the narrow, steeple-like tree commonly planted throughout the State. It is a very emphatic tree and is like an exclamation point in the landscape. Sometimes such tall emphatic points are very much desired, and at present there is no other tree so satisfactory as the Lombardy Poplar to produce this effect. But it is brittle and short-lived, and suckers abundantly. For these reasons it should be planted very sparingly. If it must be used, it should have good soil, and plenty of it. The White, or Silver, Poplar (*Populus alba*) has striking foliage, green above and white woolly below, but it easily collects dirt and soon becomes unsightly. The tree grows very rapidly, suckers abundantly, and is likely to become a nuisance.

In contrast with such trees the Red Oak or the Sugar Maple may be considered. The Red Oak is the most rapidly growing of the Oaks, and if given good conditions it will grow from one and one-half to two feet in a season. It is much better to plant Sugar Maples and Red Oaks and treat them well, than to plant Poplars and Soft Maples and see them soon broken by storm or deteriorated by age. For very dry situations Scarlet Oak (*Quercus coccinea*) should be used rather than Red Oak.

STREET TREES

Bad Street Trees

Bad street trees are of two kinds, rapid-growing trees and conspicuous trees.

Rapid-growing Trees

Rapid-growing trees as a class are weak-wooded and short-lived. Examples are Poplars, Soft, or White, Maple (*Acer saccharinum*), Box Elder (*Acer negundo*), Hardy

Catalpa (*Catalpa speciosa*), Ailanthus, Sycamore Maple (*Acer pseudoplatanus*), Birches, Willows, European Ash (*Fraxinus excelsior*), and Tulip Tree (*Liriodendron tulipifera*).

The Tulip Tree is a tree for the open lawn with abundant space and moisture. Its wood is very brittle and is easily broken by storm.

The Ailanthus is often planted in dry tenement sections of large cities, where every spot is paved. It is useful here only because it will flourish under these hard conditions. It is neither long-lived nor durable, and becomes dangerous as it grows old. With this one exception, none of the trees named above should be allowed on city streets.

The Carolina Poplar and the Soft, or White, Maple (*Acer saccharinum* [= *A. dasycarpum*]) are planted entirely too much. It is against the law to plant either of these trees in many eastern cities, and also farther west, as in Cleveland and Minneapolis. In Washington, D. C., these trees are being taken out and other trees planted in their places. They break easily in a storm, heave up the pavements, and get into the sewer pipes. They should not be used as street trees under any conditions.

The Box Elder, or Ash-leaved Maple (*Acer negundo*), is another worthless tree for the street. It is a small, straggling tree, good for holding a bank because it grows and spreads so rapidly. It is used in western street planting because it is resistant to drought; but there is no justification for it in the East, where one may have such sterling good trees as Elms, Oaks, Oriental Planes, and Sugar and Norway Maples. (See descriptions under *Good Street Trees*, below.)

Conspicuous Trees

Conspicuous trees that have attractive flowers and fruits to invite injury by vandalism are also bad trees for the street. Examples of this class are Horse-chestnut (*Æsculus hippocastanum*), Western Catalpa (*Catalpa speciosa*), Common, or Black, Locust (*Robinia pseudacacia*), Flowering Dogwood (*Cornus florida*), Magnolia (either *Magnolia conspicua* or *M. soulangeana*, and the like), Mountain Ashes (*Sorbus americana* and *S. aucuparia*), Hickory, Chestnut, and others.

The Horse-chestnut, like the Soft Maple, is planted far too much on city streets. It is a tree for the open lawn, and when set in the average dry city street it not only invites vandalism by its flowers and fruits, but also invariably suffers from lack of water and becomes unsightly before the summer is over.

The Hardy Catalpa is both weak-wooded and conspicuous in flower. It also has large, tender leaves, which easily collect dust and become torn and ragged in a storm.

The Beech (Fagus) is not suitable for street planting, although it is not mentioned above. It is hard to get established, casts a dense shade, and is worthless in dry soil.

Good Street Trees

(See descriptions below)

For Narrow Streets (less than 60 feet between buildings).— The trees should be planted alternately and spaced 40 feet apart. The following may be used: Pin Oak (*Quercus palustris*), Green Ash (*Fraxinus pennsylvanica* var. *lanceolata*), Honey Locust (*Gleditsia triacanthos*).

NOTE.—In dry tenement districts, where every spot is paved, Ailanthus should be used as recommended above.

For Medium Streets (from 60 to 90 feet between buildings).— Trees should be spaced 40 feet apart. The following may be used: Oriental Plane (*Platanus orientalis*), Norway Maple (*Acer platanoides*), Maidenhair Tree (*Ginkgo biloba*).

For Wide Streets (over 90 feet between buildings).— The trees should be spaced 50 feet apart, and where possible they should be planted on the lawn 6 feet inside the sidewalk line. This should be agreed upon and carried out uniformly by all property owners on the street. The following may be used: American, or White, Elm (*Ulmus americana*), Red Oak (*Quercus rubra*), Sugar Maple (*Acer saccharum*).

Descriptions (Arrangement is alphabetical by scientific names)

Norway Maple (*Acer platanoides*). A tough, hardy, symmetrical tree, adaptable to many conditions and enduring the smoke, dust, and drought of the city. An excellent tree, but too broad and low-headed for streets with wires, even if the wires are carried on the proper low 18-foot pole with horizontal arm.

Sugar, or Hard, Maple (*Acer saccharum*). An excellent tree for wide streets, but one that needs moisture. It always suffers from the smoke, dust, and reflected heat of the city pavement. It is also deteriorating throughout the State because of its being planted in narrow streets, where there is not sufficient moisture.

Tree of Heaven (*Ailanthus glandulosa*). The best of all trees for the dry paved tenement district. This species will grow anywhere, endures smoke and dust, and has rich, luxuriant foliage, without casting dense shade. The tree grows rapidly. The wood is brittle, and the tree is likely to be dangerous when old. Staminate (male) trees have an offensive odor for a few days during bloom, but should be used in order to avoid the unsightly fruit clusters, which hang on the pistillate trees all winter.

Hackberry (*Celtis occidentalis*). Better than the American Elm for smoky and dry situations. Of medium size, and hence adapted to average streets. In the Eastern States the Hackberry has suffered from a twig blight and from attacks by a gall insect which stings the buds.

White, or American, Ash (*Fraxinus americana*). A large tree, for use in suburbs where the soil is good and there is considerable moisture. The foliage is light, appears late and drops early, and is not eaten by the gypsy moth.

Green Ash (*Fraxinus pennsylvanica* var. *lanceolata*). Small and hardy. Grown for narrow streets where only moderate shade is wanted.

Maidenhair Tree (*Ginkgo biloba*). Hardy as far north as Boston, Buffalo, Cleveland, and Springfield (Illinois). Grows rapidly on almost any soil. Develops a cylindrical or conical head, and has light foliage, both of which characters adapt it for use on streets of average width. The tree remains narrow for forty or fifty years and then broadens out with wide-reaching limbs. The nuisance arising from its fleshy, oily fruits on pavements is obviated by using only male trees. This variety is increasing in favor and promises to be one of the most valuable of street trees. It is less injured by insects than any other street tree.

Honey Locust (*Gleditsia triacanthos*). Is very hardy, and grows well on many soils. Foliage light, opening late in spring and dropping early in the fall. Good for streets or courtyards where dense shade is not wanted. Of medium size. A thornless variety can be procured.

Sweet, or Red, Gum (*Liquidambar styraciflua*). A common native tree in the South, and hardy as far north as is the Ginkgo. It is one of the best street trees, having attractive, star-shaped, glossy foliage, and a beautiful autumn color. It thrives best in moisture, and therefore grows better in clay than in sand, but it adapts itself to many conditions. The tree is of medium size, with a narrow, symmetrical crown.

Tulip Tree, or Whitewood (*Liriodendron tulipifera*). A large, magnificent tree for use in suburbs. Requires rich, well-drained soil and plenty of room. Foliage clean and glossy, little infested by insects. The wood is very brittle and the limbs break easily.

Oriental Plane (*Platanus orientalis*). An excellent street tree, medium to large in size. Grows rapidly and is symmetrical. Has good foliage, little infested by insects. A favorite tree in Paris and Washington, which have the best street trees in the world. Not injured by the twig blight, which is often so serious on the native Sycamore (*Platanus occidentalis*).

Scarlet Oak (*Quercus coccinea*). Resembles Red Oak, but grows better in dry soil.

Pin Oak (*Quercus palustris*). Of medium size, but taller and more slender and formal than most oaks. Stem very straight, lower branches drooping. Grows best in a moist situation, but adapts itself to other conditions. The best of all the Oaks for narrow or medium streets.

Red Oak (*Quercus rubra*). Valuable for wide suburban streets. Cannot grow in pavements, but will stand comparatively poor and dry soil. Grows more rapidly than any other Oak, but does not thrive in wet situations.

European Linden (*Tilia europæa*). Much better than the native Basswood for streets. More formal in outline and more rapid in growth than the Maples and Oaks named above. When once established it will withstand dry city conditions very well. It may be used on both medium and narrow streets.

American Elm (*Ulmus americana*). The best of all street trees when given a proper situation in a suburb with open parking space between walk and curb, and with good air and water. The tree reaches a height of from 80 to 100 feet.

HEDGE PLANTS

Plants used in a hedge should be kept broad at the bottom and narrower at the top. This gives the lower branches more light and keeps them from dying out. A hedge should be trimmed before growth starts in the spring, and again lightly in late summer or fall, merely to even up long and irregular growth.

LARGE (From 7 to 10 feet)

Deciduous.— Ibota Privet (*Ligustrum ibota*). Amur Privet (*Ligustrum amurense*). Common Privet (*Ligustrum vulgare*). Buckthorn (*Rhamnus cathartica*). European and American Hornbeam (*Carpinus betulus* and *C. caroliniana*). American Beech (*Fagus ferruginea* [=*F. americana*]). The first three named are the best deciduous hedge plants for the North. The Common Privet (*Ligustrum vulgare*) is more nearly evergreen than the other two, retaining good foliage until Christmas. The California Privet (*Ligustrum ovalifolium*) is a Chinese plant introduced through California and much used for hedges, especially farther south. It is nearly evergreen, like the Common Privet, but is often killed to the ground even in southern New York.

Evergreen.— Arbor Vitæ, or White Cedar (*Thuya occidentalis*). Norway Spruce (*Picea excelsa*). Hemlock (*Tsuga canadensis*). Hemlock is the most expensive, but is the finest, of all these. Retinosporas (Chamæcyparis) are sometimes used, but are not so satisfactory in the North as is Hemlock or Arbor Vitæ. The same is true of Japanese Holly (*Ilex crenata*), which is the handsomest hedge plant on the market, but, like California Privet, is not safe for general recommendation north of New York City. A small-leaved form known as var. *microphylla* has grown for several years, unprotected, in the Rochester parks and in the Arnold Arboretum at Boston, and is well worthy of trial.

SMALL (From 3 to 5 feet)

Deciduous.— Regel's Privet (*Ligustrum ibota* var. *regelianum*); from 4 to 6 feet high, a lower form of the Ibota Privet and the most graceful of all Privets. Japanese Barberry (*Berberis thunbergii*); dense and graceful, and needing very little pruning; the best small hedge plant. Japanese Quince (*Cydonia japonica*); coarser than the Japanese barberry, and very subject to San José scale. Siberian Dogwood (*Cornus alba* var. *sibirica*); this should be cut to the ground in the spring; vigorous growth results, making bright red stems which are very attractive throughout the winter.

Evergreen.— Box (*Buxus sempervirens*); not hardy in all parts of the State, but practically the only common evergreen for a small hedge. Japanese Box (*Buxus japonica*); a hardy Box just coming into commercial use; the foliage is a bright or a yellowish green; as a specimen plant this is also looser and more graceful than *B. sempervirens*. *Evonymus radicans*; this is the original type, with small, narrow leaves, from which the larger-leaved varieties, *vegeta* and *carrieri*, have developed; it will surely prove successful in small hedges as soon as it is better known; a variegated form is already on the market. Dwarf Japanese Yew (*Taxus cuspidata* var. *brevifolia*); this is a very handsome, compact form; like the original type (*T. cuspidata*), it is very hardy and remains a rich dark green all winter, even in full sunlight; it will endure clipping, and is certain to prove of great value in landscape work in the future. (See *Evergreen Shrubs*, below, and *A New Nursery List*, page 857.) Two other dwarf evergreens should be tried for low hedges: *Taxus baccata* var. *repandens*, a low, hardy form of the English Yew, with graceful, recurving habit; and *Juniperus sabina* var. *tamariscifolia*, a very neat, picturesque Juniper. (See *A New Nursery List*, page 857.)

SHRUBS

Evergreen Shrubs

(Arrangement is alphabetical by scientific names. See *Low Woody Plants for Ground Cover*, page 852; *Low Woody Plants for Rock Garden or Small Edging*, page 853)

Andromeda [= *Pieris*] *floribunda*. Low and compact, from 2 to 3 feet high.

Evonymus radicans in variety. A shrubby vine. (See *Vines for Brick and Stone*, page 849.)

Inkberry (*Ilex glabra*). A graceful shrub, from 3 to 4 feet high. Berries black.

American Holly (*Ilex opaca*). A small tree, hardy as far north as Cape Cod. Leaves evergreen and berries red. Very difficult to transplant. Best when moved in spring with leaves stripped off.

Juniperus communis var. *montana* (= var. *adpressa* and var. *nana* in commerce). This is a low form of the Common Juniper. The shrub spreads into broad mats about 1 foot high. The foliage often becomes brown in winter, like that of the Red Cedar.

Juniperus sabina. A shrub from 4 to 6 feet high, with spreading branches. The foliage is dark green all winter. The plant is very hardy, and will grow in dry, stony soil.

Mountain Laurel (*Kalmia latifolia*). The best broad-leaved evergreen shrub for general use, growing from 5 to 8 feet high, or higher. The plant is not so exacting as is Rhododendron, although the best growth results when soil conditions are as those described below for Rhododendrons. The foliage does not curl up in cold weather as Rhododendron foliage does.

Leucothoë catesbæi. An arching shrub growing from 2 to 3 feet high, with large, dark leaves.

Oregon Grape (*Mahonia aquifolium*). The commonest Mahonia, from 2 to 3 feet high. The foliage is dark green and glossy, but it will burn in winter unless the shrub is planted where it is protected from the winter sun.

Mahonia repens. The lowest and hardiest Mahonia, 1 foot high. The foliage bronzes in winter, but does not burn even in full sunlight. (See under *Low Woody Plants for Ground Cover*, page 853.)

Rhododendrons. (See below.)

Taxus baccata var. *repandens.* Low and recurving, from 18 inches to 2 feet high. The hardiest form of English Yew. The foliage remains of a good green color in full winter sunlight.

Native Yew, or Ground Hemlock (*Taxus canadensis*). Grows best in shade. (See *Low Woody Plants for Ground Cover*, page 852.)

Japanese Yew (*Taxus cuspidata*). The best of all Yews. Foliage fine dark green, even in full winter sunlight. Plant is found in Japan in many forms, from shrubs to trees. The largest specimens in America are spreading shrubs from 8 to 10 feet high. Var. *brevifolia* is a low, compact form. (See *Hedge Plants*, page 817.)

Rhododendrons

(The five varieties marked with an asterisk are suggested as a selection. *Early* = late May; *Medium* = early June; *Late* = middle June)

Color	Variety name	Size	Blooming period
White	Boule de Neige	Small	Early
	Catawbiense album (tinged with light lavender)	Medium	Early
	*Album elegans	Large	Medium
	Delicatissimum (blush white)	Medium	Late
Pink	Carolinianum (lavender pink)	Small	Very early
	Lady Armstrong	Medium	Early to medium
	*Mrs. C. S. Sargent	Medium	Medium
Rose-colored	Roseum elegans (rosy lavender)	Medium	Early
Scarlet or crimson	Kettledrum	Small	Early
	Charles Dickens	Medium	Early
	*Caratacus	Medium	Medium
	H. W. Sargent	Medium	Late
Lavender	*Everestianum	Medium	Early
	Lady Gray Edgerton (Silvery lavender)	Medium	Medium
Purple	Kissena (petals crimped, light purple with white center; habit compact)	Medium	Early
	*Purpureum elegans	Medium	Medium

NOTE.— The red should be separated from the lavender and the purple by white. Charles Dickens and Everestianum clash if planted side by side. There should be good drainage, no lime, and plenty of fine wood soil. The roots should be kept cool and moist, winter and summer, by a mulch of leaves, and by water in summer when dry. Protection from sweeping winds should be provided, but there is no danger from exposure to the winter sun provided the roots are right.

Lilacs (Genus Syringa)

Lilac species in order of bloom (May 1 to July 1)

S. oblata, hyacinthiflora, affinis, giraldii, vulgaris varieties, *pubescens, chinensis* (Rouen Lilac), *persica, josikæa, henryi* var. *lutece, villosa, emodi, amurensis, pekinensis, japonica.* (Some of these are still rare in American nurseries.)

Varieties of Syringa vulgaris, the Common Garden Lilac (late May)

NOTE.—* indicates a good selection; ** indicates first choice. Colored varieties should be separated by white varieties unless one is sure the colors will harmonize.

White

Early single	**Marie Le Graye, Vestale Bertha Alexander, Virginalis
Medium single	Alba grandiflora, ** Frau Bertha Damman, Princess Alexander
Medium double	*Madame de Miller (dwarf)
Late single	Alba pyramidalis
Late double	Madame Lemoine, ** Miss Ellen Willmot

Pink to rosy lilac

Medium single	**Charles X (rosy lilac), Dr. Regel, Gloire de Moulins, Lilarosa, ** Machrostachia, Rubra insignis
Medium double	Antoine Buckner, Compte de Kerchove, * Emil Lemoine, Fuerst Lichenstein, Maxime Cornu
Late single	Othello

Blue to bluish lavender

Early single	**Bleuâtre, Cœrulea superba
Medium single	Jacques Callot, * Justi, Madame Briot
Medium double	Doctor Masters, ** President Grévy (semi-double), Victor Lemoine
Late single	Gilbert

Deep purple-red to reddish

Early single	**Philemon
Medium single	*Danton, Milton, Pasteur, Uncle Tom
Medium double	*Le Tour Auvergne, Maréchal de Boussompierre, Souvenir de L. Thibaut
Late single	*Aline Mocquery, ** Congo, Ludwig Spaeth, Toussaint l'Ouverture
Late double	*Charles Joly

Rouen Lilac (*Syringa chinensis* [= *S. rothomagensis*]) blooms a little later than the early varieties named above. An old, well-known form, a hybrid between the Common Lilac (*S. vulgaris*) and the Persian Lilac (*S. persica*). Has better foliage than the Persian Lilac, and a much more free and graceful habit than the Common Lilac. Both white or pale blue-lavender and reddish lavender varieties are on the market. What is commonly called Persian Lilac is usually this hybrid, the Rouen Lilac.

Garden Roses for New York State

(For Rambler Roses, see page 850; for other Roses, see index)

Hybrid Perpetuals, or Remontant
(Hardy)

White
Frau Karl Druschki
Margaret Dickson

Light pink
Mrs. John Laing
Madame Gabriel de Luizet

Pink
Magna Charta
John Hopper

Hybrid Teas
(Less hardy, but more continuous in bloom, than hybrid perpetuals)

White
White Killarney
Kaiserin Augusta Victoria

Pink
Killarney
Caroline Testout

Crimson
Gruss an Teplitz
G. B. Clark

Hybrid Perpetuals, or Remontant
(Hardy)

Carmine-pink
Paul Neyron
Mrs. R. G. Sherman Crawford

Cherry red
Ulrich Brunner
Marshall P. Wilder

Bright crimson
Alfred Colomb
General Jaqueminot

Dark crimson and maroon
Earl of Dufferin
Pierre Notting

Yellow or orange
Ulster
Soleil d'Or

Hybrid Teas
(Less hardy, but more continuous in bloom, than hybrid perpetuals)

Yellow or orange
Dean Hole
Gloire de Dijon
Mrs. Aaron Ward

NOTE.— Another yellow Rose, hardier than any of the above, is Harrison's Yellow. This is an old favorite, and is perfectly hardy without protection of any kind. It is a vigorous grower, with an abundance of pale yellow, semi-double flowers early in June. It is believed to be a hybrid of the Scotch Rose (*Rosa spinosissima*) and the Austrian Brier, which has been known by several names, such as *Rosa eglanteria*, *R. lutea*, *R. sulphurea*, and so forth, but is now called *Rosa fœtida*. The Persian Yellow is a double form of the Austrian Brier (*Rosa fœtida* var. *plena*); the Copper Austrian is another variety (*Rosa fœtida* var. *bicolor*), with flowers orange inside and yellow outside. All these forms of *Rosa fœtida* are very handsome, but in the Northern States they are short-lived and lack the vigor of Harrison's Yellow.

Regarding the pruning of Roses, it must be remembered that both Harrison's Yellow and all the *Rosa fœtida* forms produce their flowers from the upper ends of the old wood, and therefore will stand very little pruning. The process should be one of thinning out, rather than cutting back, and should consist mainly in the removal of weak, diseased, or unnecessary wood. In this respect these Brier Roses are like all the hardy Shrub and Rambler Roses, and differ entirely from the Garden Roses listed above. Hybrid Perpetual, or Remontant, and Tea Roses are cut back one-half in the fall, and again in the spring to eight or ten inches above the ground.

Berry-bearing Shrubs

(Deciduous unless otherwise stated. Arrangement is alphabetical by scientific names)

Small (From 2 to 4 feet)

NOTE.— The plants in this group sometimes reach 5 or 6 feet in height, but they are not rank growers and can be easily cut back if they become too large.

Red Chokeberry (*Aronia* [=*Pyrus*] *arbutifolia*). Berries red.
Black Chokeberry (*Aronia* [= *Pyrus*] *nigra*). Berries black.

NOTE.— These two Aronias will grow from 6 to 8 feet high, but are best if kept low and vigorous by frequent thinning out and renewal from the base.

Japanese Barberry (*Berberis thunbergii*). Berries scarlet.
Inkberry (*Ilex glabra*). A slender, bushy evergreen, with glossy leaves and black berries.
Regel's Privet (*Ligustrum ibota* var. *regelianum*). A low form of the Ibota Privet, from 4 to 6 feet high, and the most graceful of all the Privets. Berries small, blue-black with gray bloom, in lateral nodding clusters. (See page 827.)
Wild Roses, especially *Rosa lucida*.
Snowberry (*Symphoricarpos racemosus*). Berries white.
Coralberry (*Symphoricarpos vulgaris*). Berries dark red.
Maple-leaved Viburnum (*Viburnum acerifolium*). Berries black.

Medium (From 6 to 8 feet)

Common Barberry (*Berberis vulgaris*). Berries dark red.
Silky Dogwood (*Cornus amomum* [= C. *sericea*]). Berries blue or bluish white.

Panicled Dogwood (*Cornus paniculata* [= *C. candidissima*]). Berries white, on pink stems.
Red Osier Dogwood (*Cornus stolonifera*). Berries white.
Gumi (*Elæagnus multiflora* [= *E. longipes*]). Berries red and edible, ripening in late June or early July.
Winterberry (*Ilex verticillata*). Berries orange all winter. These plants are diœcious (that is, the sexes are separated, on different plants), and fruiting plants must be selected.
Bayberry (*Myrica carolinensis*). (See also *M. cerifera* in index.) Has beautiful gray, waxy, fragrant berries all winter. Plants are diœcious, like Winterberry.
Roses, especially the Japanese roses *Rosa rugosa* and *R. multiflora*, and the Sweetbrier *R. rubiginosa*.
Red Elderberry (*Sambucus racemosa*). Red in July at the same time when the Black Elderberry (*S. canadensis*) is in white flower. (See *S. canadensis*, under *Large*.)
High Bush Blueberry (*Vaccinium corymbosum*). Has beautiful small, creamy white flowers, abundant, edible fruit, and splendid scarlet foliage in the fall.
Withe-rod (*Viburnum cassinoides*). Berries first pink and then bluish black.
Viburnum dilitatum. Has small red berries.
Viburnum wrightii. This and *V. opulus* are the best red-berried Viburnums. Berries are larger than those of *V. dilitatum*, and foliage is a handsome dark glossy green.

Large (From 10 to 15 feet)
Alternate-leaved Dogwood (*Cornus alternifolia*) A small tree, to 20 feet, with blue berries on red stems.
Flowering Dogwood (*Cornus florida*). A small tree, to 20 feet, with shining red berries.
Washington Thorn (*Cratægus cordata*). The finest of all the Thorns. Has small, orange-red berries in clusters all winter. (See page 833.)
American Holly (*Ilex opaca*). A small evergreen tree, hardy to Cape Cod, very difficult to transplant. Best moved in spring with leaves stripped off. Berries red.
Ibota Privet (*Ligustrum ibota*). Habit light and spreading. Berries small, blue-black with gray bloom, in lateral nodding clusters.
Common Privet (*Ligustrum vulgare*). Berries black and shining. (See page 834.)
Tartarian Honeysuckle (*Lonicera tatarica*). The common Bush Honeysuckle. Berries reddish in early July.
Buckthorn (*Rhamnus cathartica*). Berries black.
Common Black Elderberry (*Sambucus canadensis*). Berries black.
Mountain Ash (*Sorbus americana* [native] and *S. aucuparia* [European]). The latter is the form more common in cultivation. A tree, to 40 feet, with handsome orange berries in nodding clusters all winter.
Symplocos cratægoides. Berries a beautiful clear intense blue.
Arrowwood (*Viburnum dentatum*). Berries blue to bluish black.
Wayfaring Tree (*Viburnum lantana*). Berries red, changing to almost black, very handsome.
Nannyberry (*Viburnum lentago*). Berries blue-black, with gray waxy bloom, edible.
High Bush Cranberry (*Viburnum opulus*). Berries red and acid.
Black Haw (*Viburnum prunifolium*). Berries blue-black, with gray waxy bloom, edible.

Vines with Attractive Fruits

(Arrangement is alphabetical by scientific names)

Ampelopsis heterophylla. Foliage light green, grapelike. Berries greenish white, tinged first with pink and then with light blue, very distinct.
Virginia Creeper, or Five-leaved Ivy (*Ampelopsis quinquefolia*, now called *Parthenocissus quinquefolia*). Has dark blue berries on red stems.
Climbing Bittersweet (*Celastrus scandens*). Has orange and red berries all winter.
Clematis tangutica. A handsome new plant. Fruit tassels yellow and nodding, more plumelike than those of *C. virginiana*.
Virgin's-bower (*Clematis virginiana*). Vine covered with a mass of feathery white fruits.
Evonymus radicans var. *vegeta*. The hardiest evergreen vine. Fruits orange and red, like those of Bittersweet, but care must be taken to get fruiting forms.
Chinese Matrimony Vine (*Lycium chinense*). Berries bright red.

Woody Plants with Fruits Attractive to Birds

(Prepared by R. E. Horsey and William L. G. Edson, of Rochester, New York)

NOTE.—Plants marked with an asterisk are also attractive as nesting sites. Those marked with two asterisks have fruit in winter, furnishing food for birds. Arrangement is alphabetical by scientific names.

*Five-leaved Ivy, or Virginia Creeper (*Ampelopsis quinquefolia*, now called *Parthenocissus quinquefolia*).

Boston Ivy (*Ampelopsis veitchii* [= *A. tricuspidata*], now called *Parthenocissus tricuspidata*).

Red and Black Chokeberries (*Aronia* [= *Pyrus*] *arbutifolia* and *A. nigra*).

Spicebush (*Benzoin æstivale* [= *B. odoriferum*]).

* **Japanese Barberry (*Berberis thunbergii*). The berries are not often eaten when other fruits are abundant, but the shrubs furnish good nesting sites.

* **Common Barberry (*Berberis vulgaris* and varieties).

**Black, or Cherry, Birch (*Betula lenta*).

**Yellow Birch (*Betula lutea*).

Red Birch (*Betula nigra*). All the birches furnish food in fall and winter except the Red, or River, Birch, the fruit of which ripens from June to September.

**White Birch (*Betula pendula* [*B. alba*] and *B. papyrifera*).

Hackberry (*Celtis occidentalis*).

*Dogwoods (*Cornus alba*, *C. alternifolia*, and *C. circinata*).

* **White-flowering Dogwood (*Cornus florida*). Very desirable for its ornamental value, both in flowers and in fruits, as well as for bird food.

*Cornelian Cherry (*Cornus mas*.)

* **American Hawthorns (*Cratægus coccinea* and allied species).

* **English Hawthorn (*Cratægus oxyacantha*).

**Weigela, or Diervilla (*Diervilla hybrida* in variety). The seeds are freely eaten in winter by slate-colored juncos, tree sparrows, redpolls, and pine siskins.

**Oleaster, or Wild Olive (*Elæagnus angustifolia*).

Gumi (*Elæagnus multiflora* [= *E. longipes*]).

Japanese Oleaster (*Elæagnus multiflora* var. *ovata*). As soon as the fruit ripens in July it is attacked by robins, catbirds, and cedar waxwings, and the tree is soon stripped.

*Spindle Tree (*Evonymus bungeana*, *E. sieboldiana*, and *E. europæa*. Fruits are eaten by the myrtle warbler.

Wintergreen (*Gaultheria procumbens*).

Black Huckleberry (*Gaylussacia resinosa* [= *G. baccata*]).

**Shrubby St.-John's-wort (*Hypericum prolificum*). In winter slate-colored juncos, tree sparrows, and redpolls are always found feeding on the minute seeds of this plant.

* **Common Juniper (*Juniperus communis*).

* **Irish Juniper (*Juniperus communis* var. *hibernica*).

* **Red Cedar (*Juniperus virginiana*). A favorite food of cedar waxwings and myrtle warblers.

**American and European Larches (*Larix americana* and *L. europæa*).

* **Common Privet (*Ligustrum vulgare*).

Bush Honeysuckles (*Lonicera bella* and varieties). These are hybrids of *L. morrowii*. and *L. tatarica*.

Japanese Honeysuckle (*Lonicera japonica*).

Morrow's Honeysuckle (*Lonicera morrowii*). Very attractive to birds.

Ruprecht's Honeysuckle (*Lonicera ruprechtiana*).

*Tartarian Honeysuckle (*Lonicera tatarica*).

*Matrimony Vines (*Lycium halimifolium* and *L. chinense*).

Partridge Berry (*Mitchella repens*).

Mulberries (*Morus alba* and *M. rubra*). One of the best bird foods.

**Bayberry, or Candle-berry (*Myrica carolinensis*). (See also *M. cerifera* in index.) The best food to attract and hold the myrtle warblers.

*Sour Gum, or Tupelo (*Nyssa sylvatica*).

*White, Black, and Japanese Spruces (*Picea canadensis* [= *P. alba*], *P. mariana* [= *P. nigra*], and *P. polita*).

* **Austrian Pine (*Pinus austriaca*).

* **Red Pine (*Pinus resinosa*).

* **White Pine (*Pinus strobus*).

NOTE.— All the Pines attract crossbills and grosbeaks.

Mahaleb Cherry (*Prunus mahaleb*). The best of the wild-cherry bird foods.
European Bird Cherry (*Prunus padus*).
Wild Red, or Bird, Cherry (*Prunus pennsylvanica*).
Sand Cherry (*Prunus pumila*).
Wild Black Cherry (*Prunus serotina*).
* **Flowering Crab (*Pyrus floribunda*). The best winter food for cedar waxwings, robins, northern flickers, pheasants, and pine and evening grosbeaks.
* **Buckthorn (*Rhamnus cathartica*).
Fragrant Sumac (*Rhus canadensis* [= *R. aromatica*]).
*Shining Sumac (*Rhus copallina*).
**Smooth Sumac (*Rhus glabra*).
**Staghorn Sumac (*Rhus typhina* [= *R. hirta*]).
Mountain Currant (*Ribes alpinum*). The most desirable of the Currants.
Buffalo Currant (*Ribes aureum*).
Blackberries and Raspberries, as **Rubus allegheniensis*, *R. occidentalis*, and *R. odoratus*.
*Black Elderberry (*Sambucus canadensis*).
Red Elderberry (*Sambucus racemosa* [= *S. pubens*]). The best of the Elders for bird food.
Sassafras (*Sassafras officinale* [= *S. variifolium*]).
Buffalo Berry (*Shepherdia argentea*).
Rabbit Berry (*Shepherdia canadensis*).
*Greenbrier (*Smilax rotundifolia*).
Nightshade, or Bittersweet (*Solanum dulcamara*).
**Mountain Ash (*Sorbus americana* and *S. aucuparia*). As the bright red berries hang on the trees, about Christmas time, these trees add to a winter landscape by their ornamental appearance. They also furnish very good bird food.
*Snowberry (*Symphoricarpos racemosus*).
*Coralberry (*Symphoricarpos vulgaris*).
Hemlock (*Tsuga canadensis*).
*American, English, and Scotch Elms (*Ulmus americana*, *U. campestre*, and *U scabra*). These trees furnish food for goldfinches and nesting sites for Baltimor orioles.
Blueberries (*Vaccinium corymbosum* in variety).
*Viburnums (*Viburnum acerifolium*, *V. dentatum*, *V. lantana*, *V. lentago*, *V. prunifolium*, *V. pubescens*, *V. tomentosum*, and *V. venosum*).
High Bush Cranberry (*Viburnum opulus*).
Grapes (Vitis).

Woody Plants with Good Autumn Color

(Those marked with an asterisk are the best. Arrangement is alphabetical by scientific names)

Red or orange

**Acer ginnala*. A shrub or small tree, to 20 feet, of very brilliant autumn color.
*Red Maple (*Acer rubrum*). Foliage changes color early, and sometimes is a clear yellow instead of red.
*Sugar Maple (*Acer saccharum*).
Shadbush, or Juneberry (*Amelanchier canadensis*).
*Five-leaved Ivy, or Virginia Creeper (*Ampelopsis quinquefolia*, now called *Parthenocissus quinquefolia*). Changes early; the first vine to color in the fall.
*Boston Ivy (*Ampelopsis veitchii* [= *A. tricuspidata*], now called *Parthenocissus tricuspidata*).
*Red and Black Chokeberries (*Aronia* [= *Pyrus*] *arbutifolia* and *A. nigra*).
*Japanese Barberry (*Berberis thunbergii*).
Hornbeam, Ironwood, or Blue Beech (*Carpinus caroliniana*).
*Dogwoods (Cornus). Practically all are colored red in the fall except *C. paniculata*, which is rather a dark reddish purple.
Washington Thorn (*Cratægus cordata*). The finest of the Thorns. Has very attractive fruits, and also good autumn color.
Spindle Tree (Evonymus). Nearly all species have handsome fall color, especially the *Winged Evonymus (*Evonymus alata*).
Black Huckleberry (*Gaylussacia resinosa* [= *G. baccata*]).
*Sweet, or Red, Gum (*Liquidambar styraciflua*).
*Sour Gum, or Tupelo (*Nyssa sylvatica*).

Sorrel Tree, or Tree Andromeda (*Oxydendrum arboreum*).
Pyrus simonii. The most ornamental Pear. Foliage thick and shining, turning bright red in the fall.
*Scarlet Oak (*Quercus coccinea*).
Pin Oak (*Quercus palustris*).
*Chestnut Oak (*Quercus prinus*). Foliage a rich bronze-red.
Red and Black Oaks (*Quercus rubra* and *Q. velutina*).
*Sumacs (Rhus). All species have gorgeous red and orange colors in the fall.
Flowering, or Buffalo, Currant (*Ribes aureum* [= *R. odoratum*]).
Wild Roses, as *Rosa lucida*.
Blackberries and Raspberries (Rubus), as *R. allegheniensis* and *R. occidentalis*, and the semi-evergreen trailing Swamp Dewberry (*R. hispidus*).
*Sassafras (*Sassafras officinale* [= *S. variifolium*]).
*Bridal Wreath (*Spiræa prunifolia* var. *flore pleno*).
**Syringa oblata*. The only lilac to change color in the fall. Foliage thick and of handsome color, dark, almost bronze-red.
*Blueberries (Vacciniums, especially *Vaccinium corymbosum* and *V. pennsylvanicum*).
*Viburnums. All the native species and most of the common cultivated forms have wonderful red and orange colors, except the Maple-leaved Viburnum (*Viburnum acerifolium*), which is pink or rose, tinged with purple, and the Downy Arrowwood (*V. pubescens*), which, like *Cornus paniculata* among the Dogwoods, is more purplish or bronze-red.
Crimson Glory Vine (*Vitis coignetiæ*). Most hardy grapes have a yellow autumn color, but this Japanese vine is a bold, vigorous type with crimson color in the fall.

Yellow

Norway Maple (*Acer platanoides*).
Horse-chestnut (*Æsculus hippocastanum*).
Aralia pentaphylla [= *Acanthopanax pentaphyllum*].
*Birches (Betula).
Hardy, or Western, Catalpa (*Catalpa speciosa*).
*Climbing Bittersweet (*Celastrus scandens*).
Yellowwood (*Cladrastis lutea* [= *C. tinctoria*]).
American, or White, Ash (*Fraxinus americana*). Foliage also purplish.
*Maidenhair Tree (*Ginkgo biloba*).
Honey Locust (*Gleditsia triacanthos*).
Kentucky Coffee Tree (*Gymnocladus dioica*).
Butternut (*Juglans cinerea*).
Black Walnut (*Juglans nigra*).
*Tulip Tree, or Whitewood (*Liriodendron tulipifera*).
Hop Hornbeam (*Ostrya virginiana*).
*Poplars (Populus).
Common, or Black, Locust (*Robinia pseudacacia*).
Linden, or Basswood (Tilia).
*American, or White, Elm (*Ulmus americana*).
*Grapes (Vitis), native forms. A bunch of fiery sumacs behind a yellow vine-clad wall is a common sight in early October, before the frost is on the pumpkin and the woods are ablaze with autumn color.

Yellow-brown

Hickories (Carya [= Hicoria]).
American Chestnut (*Castanea americana* [= *C. dentata*]).
*American Beech (*Fagus ferruginea*). This sometimes colors a beautiful golden brown. Beech leaves are the finest leaves in the forest.

Purple

Panicled Dogwood (*Cornus paniculata* [= *C. candidissima*]).
Golden Bell (*Forsythia viridissima*).
*American, or White, Ash (*Fraxinus americana*). This is sometimes yellow.
Ibota Privet and Regel's Privet (*Ligustrum ibota*, and var. *regelianum*).
*White Oak (*Quercus alba*).
*Maple-leaved Viburnum, or Dockmackie (*Viburnum acerifolium*).
Downy Arrowwood (*Viburnum pubescens*). Bronze-red, somewhat purplish.

Shrubs Bearing Attractive Twigs through the Winter

(Arrangement is alphabetical by scientific names. See also *Specimen Trees, Picturesque*, page 812)

Striped, or Goosefoot, Maple, or Moosewood (*Acer pennsylvanicum*). A small tree. Stem and branches very smooth, striped dark green and white.
Red, or River, Birch (*Betula nigra*). Has attractive, flaky, reddish brown bark. These trees naturally grow in clumps or colonies. The River Birch seems to be less infested by the birch borer than are some other species.
Canoe Birch (*Betula papyrifera*) or Gray Birch (*Betula populifolia*). These are trees.
Siberian Dogwood (*Cornus alba* var. *sibirica*). The brightest of the red-stemmed Dogwoods.
Alternate-leaved Dogwood (*Cornus alternifolia*). A slender little tree, with branches in whorls at wide intervals, making a very distinct and attractive habit in winter.
Cornus paniculata [= *C. candidissima*]). A slender-twigged Dogwood. Grows in solid clumps or colonies. Young twigs orange-brown; older twigs gray. Berries white, on pink stems.
Green Dogwood (*Cornus sanguinea* var. *viridissima*). A green-stemmed shrub, larger and hardier than Kerria, described below.
Yellow Dogwood (*Cornus stolonifera* var. *flaviramea* [= var. *lutea*]). Twigs bright yellow.
Scotch Broom (*Cytisus scoparius*). Green. Tender in northern New York State.
Evonymus alata. A round, compact shrub, formal and stiff, with corky wings developed conspicuously on the twigs.
Kerria japonica. Twigs green. Plant often somewhat tender in New York State, the tips killing back, giving the plant an untidy appearance in late winter.
Trembling Aspen (*Populus tremuloides*). A very delicate tree when its silvery green is seen to advantage against a dark background.
Staghorn Sumac (*Rhus typhina* [= *R. hirta*]). Has large hairy twigs, bearing stiff clusters of fuzzy red berries.
Small Native Roses (*Rosa lucida* and *R. nitida*). Should be planted in mass for the red stems, and cut down every three or four years.
Black Raspberry, or Common Blackcap (*Rubus occidentalis*). Blue-gray.
Willows: *Salix alba* var. *britzensis*, red; *Salix daphnoides*, purple.

Deciduous Shrubs for Foliage

("Filler" shrubs valuable for good foliage all the time, and often bearing flowers or fruits for part of the time. Will grow in a great variety of soils and in partial shade, although nearly all will blossom, fruit, and color better in fall if in full sunlight. Good for making up the bulk of a planting. There are three groups — small, medium, and large — and in each group the arrangement is alphabetical by scientific names. For more complete descriptions of some of these plants, see *A Selected List of Seventy-five Deciduous Shrubs*, page 827.)

Small (From 2 to 4 feet)

NOTE.—Some of the plants in this group may reach 5 or 6 feet in height, but they are slow of growth and may be easily cut back if they become too large.

Aronia [= *Pyrus*] *arbutifolia* and *A. nigra* (Red and Black Chokeberries). These will grow from 6 to 8 feet high, but are best if kept low and vigorous by frequent thinning out and renewal from the base.
Berberis thunbergii (Japanese Barberry). This and *Spiræa vanhouttei*, *Lonicera tatarica*, and *Syringa vulgaris*, begin the season with new green foliage the last week in April.
Dirca palustris (Leatherwood). Grows from 4 to 6 feet high.
Hypericum prolificum (Shrubby St.-John's-wort). This is not so handsome in flower as *H. aureum* (see page 827), but its habit is less stiff and the foliage is dark glossy green, not gray-green like that of *H. aureum*.
Ligustrum ibota var. *regelianum* (Regel's Privet). A low form of the Ibota Privet, from 4 to 6 feet high, with graceful horizontal branching.
Philadelphus coronarius var. *nanus* (Dwarf Syringa). Low and compact, 2 feet high.
Prunus pumila (Sand Cherry). Will endure very little shade.

Rhamnus alpina (Alpine Buckthorn). Has thick, handsome foliage, dark and glossy.
Rhus canadensis [= *R. aromatica*] (Fragrant Sumac). Low and prostrate, in dense masses, from 2 to 3 feet high. Will endure very little shade.
Rosa lucida (4 to 6 feet), *R. nitida* (2 feet), and other species (Wild Roses). Should be cut down to the ground every three or four years. Will endure very little shade.
Spiræa cantoniensis [= *S. reevesiana*]. (See under *S. vanhouttei*, page 832.)
Spiræa thunbergii. (See page 829.)
Symphoricarpos racemosus (Snowberry).
Symphoricarpos vulgaris (Coralberry, or Indian Currant).
Vaccinium pennsylvanicum (Early Low Blueberry). From 6 to 12 inches high.
Viburnum acerifolium (Maple-leaved Viburnum). Good in woodland shade.
Viburnum opulus var. *nanum*. Low and compact, 2 feet high.
Viburnum pubescens (Downy Arrowwood). A slender woodland shrub, like *V. acerifolium*.

Medium (From 6 to 8 feet)
Aralia pentaphylla [= *Acanthopanax pentaphyllum*].
Berberis vulgaris (Common Barberry).
Cornus paniculata [= *C. candidissima*] (Panicled, or Gray-stemmed, Dogwood).
Cornus stolonifera (Red Osier Dogwood). Foliage good, but growth too rank for "filler" planting. (See page 829.)
Corylus americana and *C. rostrata* (Hazelnuts).
Lonicera fragrantissima (Fragrant Honeysuckle). A broad, symmetrical shrub, with firm, smooth foliage, green until Christmas.
Lonicera morrowii (Morrow's Honeysuckle). A broad, spreading shrub. Leaves dark green and somewhat wrinkled and leathery above, gray hairy below.
Myrica carolinensis (Bayberry). (See also *M. cerifera* in index.)
Philadelphus inodorus. The best Syringa for foliage.
Rhodotypos kerrioides (White Kerria).
Rhus copallina (Shining Sumac). Will endure very little shade.
Spiræa bracteata (sometimes called *S. rotundifolia*). Has firm, handsome, dark green foliage, remaining green until late in fall. The most picturesque winter form of all the Spiræas. Flowers white in middle June (about the second week), following *S. vanhouttei*.
Spiræa prunifolia var. *flore pleno* (Bridal Wreath). (See page 832).
Spiræa vanhouttei (Van Houtte's Spiræa). (See page 832.)
Viburnum cassinoides (Withe-rod).
Viburnum wrightii. A beautiful red-berried Viburnum, with dark, glossy green foliage.

Large (From 10 to 15 feet)
Cornus florida (Flowering Dogwood). A small tree.
Corylus avellana and *C. maxima* (Hazels). Two large cultivated forms from southern Europe. *C. maxima* produces the filberts found in the market.
Cratægus coccinea, *C. cordata*, and *C. crus-galli* (Native Thorns, or Thorn Apples). Large shrubs or small trees, sometimes 30 feet high.
Hamamelis virginiana (Witch-hazel).
Ligustrum ibota (Ibota Privet).
Ligustrum vulgare (Common Privet).
Lonicera tatarica (Tartarian Honeysuckle). The common tall Bush Honeysuckle. The plant is glabrous (smooth) throughout.
Rhamnus cathartica (Buckthorn).
Rhus glabra (Smooth Sumac). Will endure very little shade.
Rhus typhina [= *R. hirta*] (Staghorn Sumac). Will endure very little shade. This and the preceding species should be placed at the back of a planting of sumacs, *R. copallina* next, and *R. canadensis* at the very front.
Syringa chinensis [= *S. rothomagensis*] (Rouen Lilac).
Syringa vulgaris (Common Lilac).
Viburnum dentatum (Arrowwood).
Viburnum lantana (Wayfaring Tree).
Viburnum lentago (Nannyberry).
Viburnum opulus (High Bush Cranberry).
Viburnum prunifolium (Black Haw).

A Selected List of Seventy-five Deciduous Shrubs

(Good at some time of the year — if not in foliage, then in flower, fruit, or autumn color. The letter *o* indicates that the leaves are opposite, or occasionally whorled. In all other cases the leaves are alternate. There are three groups — small, medium, and large — and in each group the arrangement is alphabetical by scientific names.)

Small (From 2 to 4 feet)

NOTE.— Some of the plants in this group may reach 6 feet in height, but they are not rank in growth and can be easily cut back.

Amorpha canescens (Lead Plant) Native in Middle West — Early July, lavender. Has silvery foliage and lavender flowers, very striking. Must be used sparingly.

Aronia [= *Pyrus*] *arbutifolia* (Red Chokeberry) Native — Late May, white. Valuable for good leaves (glossy green above, white woolly below), red berries, and red autumn color. Will grow from 6 to 8 feet high, but is best if kept low and vigorous by frequent thinning out and renewal from the base.

Berberis thunbergii (Japanese Barberry) Japan — Early May, yellow. Flowers interesting but not showy. Valuable for neat, compact form, good foliage, small scarlet berries, and brillant red autumn color. An excellent shrub.

(o) *Buddleia variabilis* var. *magnifica* (Summer Lilac) China — Late July and August, dark blue. Leaves light green above, white woolly below. Valuable for arching habit, and long, narrow, terminal clusters of rich violet flowers with orange eye.

Cydonia [= *Pyrus*, or *Chænomeles*] *japonica* (Japanese Quince) Japan — Early May, red. A hardy, attractive shrub, valuable for bright red color in early spring and for good glossy foliage in summer. The plant has been widely used, especially in hedges, and has fallen into disfavor because of its liability to infestation by San José scale. San José scale, however, attacks many other ornamental plants as well, and its control is so well understood now that it is no longer feared. If bright red color is desired early in the spring, Japanese Quince may be used. Buyers should insist on obtaining good nursery stock free from scale. Grows to 6 feet high, with many varieties, from white to scarlet, in both single and double forms.

(o) *Hypericum aureum* (Golden St.-John's-wort) Native in the South — Late July and early August, yellow. A compact shrub, with gray-green foliage and large yellow flowers.

(o) *Hypericum prolificum* (Shrubby St.-John's-wort) Native in the South — Late July and early August, yellow. The flowers are smaller than those of *H. aureum*, but the plant is more graceful, with narrow, glossy green leaves.

Kerria japonica (Globeflower) Japan — Middle May, yellow. Valuable for slender green stems in winter, bright green foliage in summer, and beautiful yellow flowers, single or double, in May. The tips of the twigs sometimes winterkill, but these can be cut off in early spring. A shrub, from 4 to 5 feet high.

(o) *Ligustrum ibota* var. *regelianum* (Regel's Privet) Garden origin — Late June, white. Flowers small, not showy but very attractive, in small, nodding clusters. Berries small, blue-black with gray bloom, in nodding lateral clusters. Fall color a dull bronze-purple. This is a low form (from 4 to 6 feet high) of the Ibota Privet, and is valuable for graceful horizontal branching and good foliage. It is the best Privet for specimen planting. This and *Berberis thunbergii*, *Symphoricarpos vulgaris*, and *Viburnum acerifolium*, are excellent small "filler" shrubs, with good foliage

but not showy flowers. (See *Deciduous Shrubs for Foliage*, page 825.) They may be used where only good foliage is desired, as in very public places, or they may be planted freely to fill in between groups of other shrubs that are more showy in flower or fruit. Other good "filler" shrubs are: Medium (from 6 to 8 feet) — *Aralia pentaphylla* [= *Acanthopanax pentaphyllum*], *Berberis vulgaris*, *Cornus paniculata*, *Lonicera fragrantissima*, *Myrica carolinensis* (see *M. cerifera* in index), *Viburnum cassinoides*; Large (from 10 to 15 feet) — *Cratægus coccinea*, *C. crus-galli*, and (especially) *C. cordata*, which is more upright and treelike, to 30 feet high, *Hamamelis virginiana*, *Ligustrum ibota* and *L. vulgare*, *Lonicera tatarica*, *Rhamnus cathartica*, *Viburnum dentatum* and *V. lentago* — the latter Viburnum being the taller and more treelike.

(o) *Philadelphus lemoinei*
(Lemoine's Syringa)
Garden origin

Late June, white. Has fairly good foliage, but is especially valuable for graceful habit and for mass of white flowers. The varieties Avalanche, Candelabre, and Gerbe de Neige are the best.

Rhus canadensis [= *R. aromatica*]
(Fragrant Sumac)
Native

Early May, yellow. Flowers attractive in mass, but not showy. Valuable for good foliage (leaves trifoliate, like a clover leaf, but much larger), hairy red berries, beautiful red autumn color, and low prostrate habit (3 feet high) forming dense masses.

Rosa lucida
(Glossy Rose)
Native

Middle June, pink. Valuable both for flowers and glossy foliage, and for red fruits and winter stems. Should be cut down to the ground every three years. A shrub, from 4 to 6 feet high.

Rosa rugosa
(Japanese Rose)
Japan

Early June, white, pink, or red. Either single or semi-double, according to variety. Valuable for flowers, large orange-colored fruits, and heavy, wrinkled, dark green leaves. A very hardy, vigorous rose, from 4 to 6 feet high.

Rosa setigera
(Prairie, or Michigan, Rose)
Native

Middle July, pink. Valuable for large, late flowers, and vigorous arching habit (from 4 to 6 feet high). The parent of such ramblers as Baltimore Belle, Prairie Queen, and others. The white Memorial Rose from Japan (*Rosa wichuraiana*), which is distinctly prostrate and vinelike, is blooming at the same time. The Memorial Rose is the parent of many of our newer late-blooming Ramblers, such as Dorothy Perkins, Hiawatha, Albéric Barbier, and Excelsa, which are also blooming at this time. (See Rambler Roses in order of bloom, under *Flowering Vines*, page 850.)

Rosa spinosissima
(Scotch Rose)
Europe to Siberia

Early June, white, with yellow stamens. A charming Rose. Altaica is the best variety.

Rose, Tausendschön
(Thousand Beauties)
Garden origin

Middle June, pink. Is really a Rambler, but is also excellent without support in the front of a border. The finest of the early Ramblers, blooming before the Crimson Rambler. Light pink in color, larger and better than the later Dorothy Perkins.

Spiræa albiflora
Japan

Late July, white. Flowers in flat heads. A low, stiff shrub, 18 inches high. Branches angular, leaves narrow and glabrous (smooth).

Spiræa bumalda
Anthony Waterer variety
Garden origin

Late July, bright red. A popular little shrub, seldom over 2 feet high, with branches more or less stiff and angular. This is one of the many hybrids between *S. albiflora* and *S. japonica*.

Spiræa japonica (Also called *S. callosa*) Japan — Early July, pink. Flowers in flat heads, like those of *S. albiflora*, but the plant is higher (4 feet), the branches are round, and the leaves are broader (ovate to oblong-lanceolate) and pale bluish green, purplish when unfolding.

Spiræa thunbergii Japan — Early May, white. Has a slender, spreading habit, early white flowers, and narrow, feathery, light green leaves. The first Spiræa to bloom. Tips of twigs often winterkill, but these may be cut off in early spring.

Spiræa tomentosa (Steeplebush) Native — August, pink. Flowers in narrow, dense spikes, young branches and leaves beneath densely yellow-brown woolly.

(o) *Symphoricarpos racemosus* (Snowberry) — July and August, white. Flowers small and inconspicuous, bell-shaped, pinkish inside. Valuable for white berries all winter, and for good foliage, the leaves being smooth below like those of *Lonicera tatarica*, but smaller and almost round.

(o) *Symphoricarpos vulgaris* (Coralberry, or Indian Currant) Native — August, greenish. Flowers small and inconspicuous. Plant a good "filler" shrub (see *Ligustrum ibota* var. *regelianum*), with foliage remaining good late in fall (but the leaves pubescent below, not glabrous [smooth] like those of *S. racemosus*), and with graceful arching branches studded with small, tight clusters of dark red berries remaining all winter.

(o) *Viburnum acerifolium* (Maple-leaved Viburnum) Native — Middle June, white. This is another good "filler" shrub, and is also excellent for planting in the shade. It has good foliage, attractive creamy white flowers, black berries, and good autumn color — pale rosy lavender.

Medium (From 6 to 8 feet)

(o) *Æsculus parviflora* (Formerly called *Pavia macrostachya*) (Dwarf Buckeye) Native in the South — Middle July, white. A shrub growing in colonies, like Sumac. Valuable for foliage and for narrow, upright spikes of white flowers in July and August.

Aralia pentaphylla [= *Acanthopanax pentaphyllum*] (Five-leaved Aralia) Japan — Has no conspicuous flower or fruit. Plant is essentially a "filler" shrub, for good foliage only. Very attractive and satisfactory.

Berberis vulgaris (Common Barberry) From Europe, but escaped and growing wild in the United States — Late May, yellow. Small flowers in hanging clusters, not showy but nevertheless very attractive. Has good foliage and good habit of growth, with clusters of dark red berries hanging all winter. The fall color, however, is not so brilliant as that of the smaller Japanese Barberry (*Berberis thunbergii*).

(o) *Cornus paniculata* [= *C. candidissima*] (Panicled, or Gray-stemmed, Dogwood) Native — Middle June, white. A slender-stemmed and narrow-leaved Dogwood, with purplish color in fall and attractive white berries on pink stems. A good "filler" shrub. (See last paragraph under *C. stolonifera*, below).

(o) *Cornus stolonifera* (Red Osier Dogwood) Native — Late May, white. Valuable for good foliage, for rapid growth, for broad-spreading habit — its lower branches prostrate and taking root — and for its white berries, fine red color in autumn, and red stems in winter. There is a yellow-twigged variety, *C. stolonifera* var. *flaviramea*, and also a related form with bright green stems, *C. sanguinea* var. *viridissima*. The Siberian

Dogwood (*C. alba* var. *sibirica*) has bright, more coral-red stems, and is considered the best red-stemmed Dogwood. These stem colors show best on young, vigorous wood, and for this reason some of the older stems should be cut out each spring, thus encouraging new growth. Hedges of Siberian Dogwood are often cut to the ground early each spring. Vigorous growth results, giving fine foliage in summer and bright red stems in winter.

It should be remembered that all the Dogwoods just mentioned are rank-growing shrubs, and therefore should be planted in solid masses or as individual specimens with plenty of room for spreading. They certainly should not be mixed indiscriminately with other good, but less vigorous, shrubs, which would suffer in the struggle and in time even be killed out. For such " filler " planting *Cornus paniculata* is much safer. (See note under *Ligustrum ibota* var. *regelianum*.)

(o) *Diervilla hybrida*
Eva Rathke variety
(Weigela)
Garden origin

Late June, red. Similar to Le Printemps, following. Eva Rathke is the best late red variety.

(o) *Diervilla hybrida*
Le Printemps variety
(Weigela)

Early June, pink. A rather coarse shrub, with only fair foliage but showy when in flower if good color varieties are used such as Le Printemps and Eva Rathke.

Elæagnus multiflora
[= *E. longipes*]
(Gumi)
Japan and China

Has inconspicuous flowers, but good foliage and edible fruit in July. (See *Woody Plants with Fruits Attractive to Birds*, page 822.)

(o) *Evonymus alata*
(Winged Evonymus)
Japan

Flowers greenish yellow, small and inconspicuous. Plant valuable for compact, symmetrical form, good foliage, and brilliant fall color. The twigs have thin, corky ridges, or " wings," which are very characteristic of the plant.

(o) *Forsythia fortunei*
(o) *Forsythia suspensa*
(o) *Forsythia viridissima*
(Golden Bell)
China

April, yellow. These are the showiest of the early yellow-flowered shrubs, and are very rapid in growth. The young twigs are square, with hollow or diaphragmed pith, never solid. There are two types, *F. suspensa* and *F. viridissima*. *F. suspensa* has an arching habit, with long, trailing branches, broad leaves (which are sometimes 3–lobed or even divided into 3 leaflets), hollow pith, two-years-old twigs yellow-brown, and autumn color dull yellow. *F. viridissima* has an upright habit, narrow leaves which are never lobed nor divided, diaphragmed pith, two-years-old twigs green, and autumn color purplish. *Forsythia fortunei* is merely a variety of *F. suspensa*, being exactly the same except that it is upright, like *F. viridissima*. *F. intermedia* is a hybrid between *F. fortunei* and *F. viridissima*, and resembles *F. viridissima* in foliage, with pith also diaphragmed or sometimes apparently hollow but diaphragmed toward the joints. These intermediate hybrids are the best-flowering of the Forsythias. *F. suspensa* is excellent for hanging over a wall or trailing down a bank. It is the only Forsythia that has a habit of growth good enough to make it attractive as an individual specimen. All the other Forsythias are best when planted in solid groups for mass effect.

(o) *Hydrangea arborescens*
var. *sterilis*
(Hills of Snow)
Garden origin

Middle July, white. This is a double form of *Hydrangea arborescens*, which is native in the South. It is valuable for round, showy heads of white flowers in midsummer. It blooms nearly a month before the commonly planted Hardy Hydrangea from Japan (*H. paniculata* var. *grandiflora*), which is a larger plant, becoming treelike if allowed to grow naturally. (This is listed below, under *Large*.) *H. paniculata* var. *grandiflora* has flowers in larger and longer (that is, more pyramidal) clusters than those of *H. arborescens* var. *sterilis*, and its leaves are short-stemmed, not long-stemmed like those of the latter.

(o) *Lonicera fragrantissima* (Fragrant Honeysuckle) China	Early May, white tinged with pale yellow. Flowers very fragrant, but small and not showy. The plant is a broad, symmetrical shrub, valuable for firm, smooth, dark green leaves, which are semi-evergreen — that is, remaining green until Christmas.
Magnolia stellata (Starry Magnolia) Japan	April, white. A symmetrical shrub, covered with a mass of bloom in April before the leaves appear. Has good green foliage.
Myrica carolinensis (Bayberry, or Candleberry) Native along the eastern coast of the United States	Flowers inconspicuous, but plant very valuable for symmetrical form, good foliage, and beautiful, fragrant, waxy, gray berries remaining all winter. The sexes are separate, and fruiting plants must be used. (See also *M. cerifera* in index.)
(o) *Philadelphus coronarius* (Syringa, or Mock Orange)	Middle June, white. An old-fashioned shrub, with a good upright habit and fragrant creamy white flowers. The bark on two-years-old twigs is reddish and peels off. A shrub, from 8 to 10 feet high.
(o) *Philadelphus inodorus* (Native in the South)	Late June, white. Has a graceful form, and dark green, almost glossy, leaves. This is the best Syringa for foliage. Flowers pure white and odorless. Bark of two-years-old twigs is reddish brown and peels off. A shrub, to 8 feet high.
Prunus triloba var. *flore pleno* (Flowering Almond) China	Early May, pink. An old favorite, bearing a wealth of double pink flowers like little roses, followed by soft, hairy leaves which are broad oval, often three-pointed. Plant not very vigorous, but well worth caring for. This and Bridal Wreath (*Spiræa prunifolia* var. *flore pleno*) make a good pink and white combination in early spring.
Rhododendron [= *Azalea*] *calendulaceum* (Flame Azalea) Native in the South	Early June, yellow or orange. Valuable for magnificent flame-colored flowers. Plant perfectly hardy in the North, blooming after the northern Pink Azalea, *R. canescens* (formerly called *R. nudiflora*).
Rhododendron [= *Azalea*] *kæmpferi* (Japanese Azalea) Japan	Middle May, scarlet. Valuable for brilliant flowers in May, a little before the northern Pink Azalea, *R. canescens* (formerly called *R. nudiflora*).
(o) *Rhodotypos kerrioides* (White Kerria) Japan	Middle May, white. A hardy shrub, resembling *Kerria japonica* in foliage but taller and more vigorous, with gray stems, opposite leaves, white flowers, and hard, black, shiny, berry-like seeds in clusters of three or four, persisting all winter.
Rosa multiflora Japan	Middle June, white. A hardy, vigorous shrub, with recurving branches, pectinate (comblike) stipules, and large clusters of small white flowers. The Chinese variety (*R. multiflora* var. *cathayensis*), just introduced by the Arnold Arboretum (see *A New Nursery List*, page 857), has larger pink flowers and is probably the original of the old double Seven Sisters rose and the later Crimson Rambler. (See Arnold Arboretum Bulletin, new series Vol. I, no. 9, June 21, 1915.)
Sorbaria [= *Spiræa*] *aitchinsonii* Afghanistan	Middle July, white. Flowers in showy feathery spikes, leaves pinnately compound like a sumac leaf, young stems smooth and red. The plant is handsomer than the earlier and commoner *Sorbaria sorbifolia*, and makes a good combination with the large, pink-spiked, July-blooming *Spiræa billardii* described below.

Spiræa billardii (Often called *S. lenneana*) Garden origin — Middle July, pink. This is a large, July-blooming Spiræa (from 5 to 6 feet high), with bright pink flowers in rather dense spikes. The plant has brown hairy stems, and the leaves on young growth are grayish hairy beneath. It is intermediate in type between the large western *Spiræa douglasii* and the smaller, earlier, eastern *Spiræa salicifolia* [= *S. alba*] (Meadow-sweet, or Queen of the Meadow). *S. douglasii* grows 8 feet high, with flowers deep pink, in dense spikes, branches reddish brown woolly, and leaves densely white woolly beneath. *S. salicifolia* is smaller (from 3 to 5 feet high), with leaves glabrous (smooth) or nearly so, stems also smooth or finely hairy when young, and flowers white or light pink, in dense pyramidal leafy clusters, beginning to bloom in early July along with *Spiræa japonica*. (In this connection see also the small [4 feet high] native *Spiræa tomentosa* [Steeplebush] described above under *Small*.) In this later-(August-)blooming Spiræa the flowers are deep pink or almost purplish, and the young stems and leaves beneath are tawny or yellowish brown woolly.

Spiræa prunifolia var. *flore pleno* (Bridal Wreath) China, Japan — Early May, white. This is an old favorite, 6 feet high, with graceful, spreading habit, but not so drooping and pendulous, and not quite so hardy, as *S. vanhouttei*. It flowers profusely before the leaves appear, about a week later than *S. thunbergii*, and so does not have the fresh early spring foliage so characteristic of the later-blooming Van Houtte's Spiræa. But its midsummer foliage is better than Van Houtte's, for, being double-flowered, no seed is developed, and the leaves are a fine glossy green, later, in autumn, coloring a rich orange-red. In midsummer Van Houtte's Spiræa has dull, almost gray-green foliage, and looks rather seedy because of the great abundance of seed following the mass of bloom in May. The foliage also remains green in fall without change of color.

Van Houtte's Spiræa has the more gracefully pendulous form, and is also very popular for its fresh early foliage and for its wealth of white bloom in late May. Bridal Wreath is more upright, with better summer foliage and fall color, and also earlier bloom, which is appreciated because it combines so well, both in color and in season, with another old favorite, the Pink Double-Flowering Almond (*Prunus triloba* var. *flore pleno*). A group of these shrubs may be placed at the back of a planting, with some *Spiræa vanhouttei* in front to face down the planting and to give both early foliage and, later, white flowers after the pink and white combination has passed.

Spiræa vanhouttei (Van Houtte's Spiræa) Garden origin — Late May, white. This is a graceful shrub, 6 feet high, with arching, almost pendulous, branches. It is a hybrid between *S. trilobata* (which is perfectly hardy but smaller, resembling *S. vanhouttei* in foliage) and *S. cantoniensis* [= *S. reevesiana*], which resembles *S. vanhouttei* in form and habit, but has narrower leaves and is smaller and somewhat tender, the tips sometimes winterkilling like those of *S. thunbergii*. (For further description of *S. vanhouttei*, see under *S. prunifolia* var. *flore pleno*, above.)

Large (From 10 to 15 feet)

Cercis canadensis (Redbud, or Judas Tree) Native — Early May, rosy purple. Valuable first for mass of small, pealike flowers before the leaves appear, and later for large, almost round, dark green leaves. The plant is a small, broad-spreading tree, from 20 to 30 feet high.

(o) *Chionanthus virginica* (Fringe Tree) Native in the South — Early June, white. An attractive shrub, with loose nodding clusters of narrow, creamy white flowers, followed by large, dark green, magnolia-like leaves and dark blue-black berries. The plant is a large, open-branched shrub or a slender, graceful tree, to 30 feet high.

Cladrastis lutea [=*C. tinctoria*] (Yellowwood) Native in the South — Middle June, white. Has hanging clusters of white, pealike flowers against a green background of pinnately compound leaves. A graceful, wide-branching tree (from 30 to 40 feet high), with short trunk, smooth gray bark, yellow wood, and yellow autumn color.

(o) *Cornus florida* (Flowering Dogwood) Native — Middle May, white. An excellent plant at all times. Grows well in either sun or shade, with good form, beautiful flowers, dark green foliage, bright red berries, and gorgeous autumn color. A large shrub or small tree, 20 feet high.

(o) *Cornus florida* var. *rubra* (Pink Dogwood) Garden origin — Like the preceding, but has pink flowers.

Cratægus cordata (Washington Thorn) Native in the South — Late June, white. The best of the Thorns. A small tree, more upright than *C. crus-galli*, with broader, more triangular leaves, and handsomer clusters of small, orange-red berries remaining all winter. The foliage is not injured by the leaf-mining insect so injurious to Cratægus in New England. 30 feet high.

Cratægus crus-galli (Cockspur Thorn) Native — Early June, white. Especially valuable for picturesque, horizontal branching, and for dark green leaves, which are thick, glossy, and wedge-shaped. A broad-spreading shrub or small tree, from 30 to 40 feet high.

Cratægus oxyacantha var. *paulii* (Paul's Double Red Thorn) Garden origin — Late May, red. This is a variety of the English Hawthorn, with showy double red flowers, compact, symmetrical form, and small, deeply lobed leaves. 15 feet high.

Hamamelis virginiana (Witch-hazel) Native — October, yellow. Very valuable as a large "filler" shrub, with good foliage, especially adapted to shade. Also has attractive small, starry, yellow flowers just as the plant is in golden autumn color, or even later after the leaves have fallen. A shrub or tree, to 20 feet high.

Hibiscus syriacus (Rose of Sharon, or Shrubby Althæa) — August, several colors — white, pink, blue, or purple. An old-fashioned shrub, indispensable with its hollyhock-like flowers in August.

(o) *Hydrangea paniculata* var. *grandiflora* (Common Hardy Hydrangea) Garden origin — August, white. This is the common "snowball" hydrangea of northern lawns. It is double, and was developed from a single-flowered form native to Japan and called *H. paniculata*. By some persons the single type is considered more graceful and attractive than the more massive *grandiflora* type. In the former the flowers are in upright pyramidal clusters and do not weigh down the branches, as in the *grandiflora* type. In the latter the flower clusters are often very dense and heavy, and change from white to light pink, but are never blue like some of the tender greenhouse forms known as *Hydrangea hortensis*. A shrub or tree, sometimes 20 feet high.

Koelreuteria paniculata (Varnish Tree) China, Japan — Middle July, yellow. Very ornamental, with large, loose, upright clusters of small yellow flowers against dark green compound leaves, followed by erect clusters of red, bladdery fruits. A round-headed tree, from 20 to 30 feet high, not so hardy and tough-wooded as one might like but much planted farther south.

Laburnum alpinum (Scotch Laburnum) Mountains, southern Europe — Early June, yellow. Flowers in long, hanging clusters, at the same time as the old familiar Harrison's Yellow Rose and the Flame Azalea (*Rhododendron* [= *Azalea*] *calendulaceum*), described on page 831. A large, upright bush or small, compact tree, from 20 to 30 feet high. Hardier than the tender, but better known, Golden Chain (*Laburnum vulgare*).

(o) *Ligustrum vulgare* (Common Privet) Europe, Asia — Late June, white. Essentially a good foliage or "filler" type of shrub, with stout, upright form, smooth, dark, semi-evergreen leaves (green until Christmas), and erect terminal clusters of white flowers followed by black, shining berries. The plant resembles the California Privet (*L. ovalifolium*), but is perfectly hardy (see *Hedge Plants*, page 817), with smaller leaves and abundant fruit. The California Privet seldom fruits in the North. *L. vulgare* has been selected for this list in preference to *L. ibota*, because it has smooth leaves and twigs that do not collect dust, and because it is semi-evergreen, retaining good foliage without change of color until Christmas. The Ibota Privet, like the Regel's Privet (described above under *Small*), has young twigs and the leaves beneath finely pubescent (hairy), berries small, blue-black with gray bloom, and foliage changing to dull purple in fall.

(o) *Lonicera tatarica* (Tartarian Honeysuckle) Russia, Siberia — Late May, white, pink, or rose, according to variety. This is one of the very best large "filler" shrubs for foliage. It is also attractive when covered with small flowers in May, and again when bearing red or orange-yellow berries in July and August. The plant is glabrous (smooth) throughout.

(o) *Philadelphus latifolius* [= *P. pubescens*, and also sometimes called *P. grandiflorus*] (Syringa) — Late June, white. This and a related form (*P. gordonianus*) are the showiest of the larger Syringas. They have abundant, large, pure white, odorless flowers at about the same time as the little Lemoine hybrids (*P. lemoinei*), but later than *P. coronarius*, with its smaller, creamy white, fragrant flowers. These are the common tall Syringas, sometimes reaching 20 feet, with large leaves, pubescent beneath, and with the bark on two-years-old twigs gray and often checking but not peeling off.

Pyrus floribunda (Flowering Crab) Garden origin — Middle May, pink. This is the first Crab Apple to bloom, coming in with Lilacs and the Flowering Dogwood. The color is a light pink, deepest in bud and almost white when fully open. The leaves and young parts are smooth, like those of the Wild Eastern Crab (*P. coronaria*), not woolly like those of the Iowa Crab or the double variety of the latter, Bechtel's Crab, described below. The leaf margins are also finely and sharply toothed, not coarsely and bluntly toothed like those of Bechtel's Crab, nor prominently lobed and notched like those of the Wild Eastern Crab. The small, pealike fruits are red, on long, slender stems, and are much liked by birds. The plant is a large, spreading shrub or a small tree.

Pyrus ioensis var. *bechtelii* (Bechtel's Crab) Garden origin — Late May, pink. A double variety of the Iowa, or Prairie State, Crab, with light pink flowers like little double roses, young growth and under surface of leaves woolly, and leaf margins coarsely and bluntly toothed. A small tree.

(o) *Rhamnus cathartica* (Buckthorn) Europe and Asia, and escaped in the United States — Has no noticeable flower, but plant is very satisfactory as a large "filler" shrub for good foliage, enduring shade, also having soft black berries very attractive to birds. The leaves are normally opposite, but are sometimes alternate on the same plant. The shrub is common in tall hedges, usually developing a twiggy, sharp-pointed growth.

Rhus cotinus (Smoke Bush) Europe, Asia — Flowers green and inconspicuous in May, but fruit purplish and very plumose in middle July, making the handsome smoky appearance which gives the plant its name. Leaves firm and smooth, broad and almost round, on long stems; twigs stiff and stout, aromatic. A large, compact shrub.

Syringa vulgaris (Common Lilac) Bulgaria — Middle May, in many colors. Both single and double. There are two types of shrubby lilacs commonly grown in gardens — *S. vulgaris* and *S. persica*. *S. vulgaris* is a large shrub, often 20 feet high, with a dense, upright habit, stout, round twigs with decurrent lines usually absent or indistinct, broad leaves, and compact, erect clusters of single or double flowers in many colors according to variety. *S. persica* is smaller (from 6 to 10 feet high), with an open, graceful habit, slender, four-sided twigs due to the evident decurrent lines running down from the bases of the leaf stalks, narrow leaves, and loose, nodding clusters of single flowers, either white (var. *alba*) or rosy lavender (var. *rubra*).

The real *S. persica* is comparatively rare in gardens. What is commonly called Persian Lilac is the Rouen Lilac (*Syringa chinensis* [= *S. rothomagensis*]). This is a hybrid between *S. vulgaris* and *S. persica*, and is intermediate in character, combining good qualities of both its parents. It is a very beautiful type, with better foliage than that of *S. persica* and a more graceful habit than that of *S. vulgaris*. It grows 12 feet high and has large, handsome, nodding clusters of whitish (pale lavender) (var. *alba*), rosy lavender (var. *rubra*), or blue-lavender flowers. (See *Lilacs*, page 819.)

(o) *Viburnum dentatum* (Arrowwood) Native — Middle June, white. An excellent shrub at all times. Has a compact form, glossy, dark green foliage, creamy white flowers, small, hard, round, dark blue berries, and finally gorgeous red autumn color. A hardy, vigorous shrub, adapting itself to dry as well as wet soils and even growing in partial shade. The leaves are coarsely and sharply toothed, and glabrous (smooth) throughout.

(o) *Viburnum lentago* (Nannyberry) Native — Early June, white. This is another sterling native plant. It has practically the same good qualities as *V. dentatum*, but it is taller (sometimes a small tree, 20 feet high) and more open-branched, with longer leaves, which are finely toothed and long-pointed. The berries are edible, being larger and more fleshy and blue-black than those of *V. dentatum*, with gray bloom.

The Black Haw (*V. prunifolium*) is very closely related to *V. lentago*, but is handsomer as an individual specimen plant. The leaves are shorter and broader for their length, and not so long-pointed. The habit of growth is also characteristic. *V. prunifolium* is denser and more compact, and is full of stout twigs and cross branches. It makes a beautiful little symmetrical tree, in which birds like to build their nests. *V. lentago* is taller, with open, more slender, spreading branches, and is better suited for mass planting in a background.

(o) *Viburnum opulus* (High Bush Cranberry) Europe, America — Early June, white. Has smooth, lobed leaves, and flat clusters of small, creamy white flowers surrounded by a ring of white, showy, sterile flowers like those in the old-fashioned Snowball, or Guelder-rose. In fact *V. opulus* is the single form from which the double-flowered Snowball has been developed.

It should be noted, however, that there are two forms of *V. opulus*, the American and the European. The American form has an open, graceful habit, foliage little infested by aphids (plant lice), bright scarlet berries, and brilliant autumn color. The European form has a denser habit, with more twisted and crooked growth, darker red berries, and foliage not only much infested by aphids but also lacking the handsome autumn color of the American form. The Snowball, or Guelder-rose, has developed from the European *V. opulus*, and both it and the European form have foliage badly twisted and curled by aphids.

WOODY PLANTS IN ORDER OF BLOOM

(Trees, shrubs, and vines)

The dates here given are general only, and are of interest mainly because they are comparative. Local conditions and seasons greatly influence the time of bloom. The forms marked with an asterisk are described above, in *A Selected List of Seventy-five Deciduous Shrubs*. All the plants are deciduous unless otherwise stated. The letter *w* before a name means *wild* — either native or escaped from cultivation.

			Height
March			
Orange and red.		*Hamamelis japonica* var. *arborea* (Japanese Witch-hazel). Often blooms in February in spite of ice and snow. A large shrub with good foliage.	10 to 15 feet
April............		The most important plants for bloom in April are the white **Magnolia stellata*, the yellow *Cornus mas* and *Forsythia, the delicate white and pink evergreen Trailing Arbutus, or Mayflower (*Epigæa repens*) (from late April to May), the red *Acer rubrum*, or native Red Maple, and the rosy lavender *Rhododendron* [= *Azalea*] *mucronulatum*, the earliest of all hardy Azaleas and Rhododendrons. (See note on Azaleas at end of *April*, page 837.)	
White.........		*Daphne mezereum* var. *album*..................	3 feet
		Erica carnea var. *alba* (Hardy Spring Heath). Evergreen..............................	6 to 12 inches
		**Lonicera fragrantissima* and *L. standishii*. Have small, fragrant, white flowers, tinged with yellow, appearing mostly before the leaves, from late April to early May. Spreading shrubs.	6 feet
		**Magnolia stellata*. A shrub....................	5 to 8 feet
Yellow....	(w)	Alnus (Alders), both wild and cultivated forms. Flowers in hanging catkins, appearing before the leaves. Large shrubs or trees.	
	(w)	*Benzoin æstivale* [= *B. odoriferum*] (Spicebush). A large shrub. (See page 811.)	10 to 15 feet
		Cornus mas (Cornelian Cherry). A small tree, blooming about a week before the Forsythias, and hardier than these but not so rapid in growth. (See page 811.)....................	15 to 20 feet
	(w)	Corylus (Hazels). Flowers in hanging catkins, appearing before the leaves. The filberts found in the market are the fruits of a cultivated hazel, *Corylus maxima*. Shrubs...............	5 to 15 feet
	(w)	*Dirca palustris* (Leatherwood). A shrub. (See page 825.)................................	4 to 6 feet
	(w)	*Forsythia (Golden Bell). (See page 830.)	
	(w)	*Salix discolor* (Pussy Willow). A common native shrub, with very black winter buds. (See page 852.)............................	10 to 15 feet
Brown....	(w)	*Ulmus americana* (American, or White, Elm.)	
Orange....	(w)	*Salix tristis* (Dwarf Willow). A dainty little shrub, with slender gray stems and leaves and attractive male catkins.....................	12 to 18 inches
		NOTE.— Both the Pussy Willow and the Dwarf Willow grow well in dry soil.	
Red.......	(w)	*Acer rubrum* (Red Maple). A large tree. (See pages 811 and 823.)	
	(w)	*Acer saccharinum* (Soft, or White, Maple). A large tree. (See page 814.)	
		NOTE.—The seeds of these early maples are ripe and fall by the first of June.	
Pink......	(w)	*Epigæa repens* (Trailing Arbutus). Late April to May. Evergreen.......................	4 inches
		Erica carnea (Hardy Spring Heath). Evergreen. (See page 854.)........................	6 to 12 inches
Rosy purple	(w)	*Daphne mezereum*............................	3 feet

April (*continued*) — Height

Rosy purple.... *Rhododendron* [= *Azalea*] *mucronulatum*. The earliest of all hardy Azaleas and Rhododendrons, about a week ahead of *R. vaseyi*. The leaves are deciduous, but they color a handsome scarlet in fall.................................. 4 to 5 feet

NOTE.—Following is a list of seven hardy Azaleas (deciduous Rhododendrons) in order of bloom; all are native, except *R. mucronulatum* from northern China, and **R. kæmpferi* (page 831) from Japan: *R. mucronulatum*, rosy lavender, middle to late April; *R. vaseyi*, light pink, early May; **R. kæmpferi*, scarlet, middle May; *R. nudiflora* (Pinkster Flower), deep pink, late May; **R. calendulaceum* (Flame Azalea), yellow and orange, early June; *R. arborescens*, white with red stamens, middle June; *R. viscosum* (Swamp Azalea), pure white, late June.

Early May...... Shadbush, or Juneberry (Amelanchier), blooms at this time, also the early Spiræas, *Thunberg's Spiræa (page 829) and *Bridal Wreath (page 832), Norway Maple and Sugar Maple, Peaches (both the orchard types and the double red-and-white ornamental forms, the second week in May), *Flowering Almond (*Prunus triloba* var. *flore pleno*, an old favorite), *Japanese Quince (*Cydonia* [= *Pyrus*, or *Chaenomeles*] *japonica*), Cherries (Prunus, both wild and cultivated, the second week in May), the Weeping Japanese Cherry (*Prunus pendula*), Plums (both the *domestica* types, the Japanese and the native Canada Plum), the white *Andromeda* [= *Pieris*] *floribunda*, a compact evergreen shrub, the large tulip-flowered Magnolias (the tree form, M. *conspicua* [= *M. yulan*], with white flowers, and the large shrub types such as *M. soulangeana*, with pinkish flowers), the rosy purple *Redbud, or Judas Tree (*Cercis canadensis*, page 832), the yellow Flowering Currant (*Ribes aureum* [= *R. odoratum*]), and last but not least *Rhododendron* [= *Azalea*] *vaseyi*, a beautiful, hardy, light pink Azalea native to the Appalachian Mountains.

White..... (w) *Amelanchier lævis* and *A. canadensis* (Shadbush, or Juneberry). Small trees.................. 30 feet

(w) *Amelanchier oblongifolia* [= *A. obovalis*]. A large shrub.................................. 10 to 15 feet

(w) *Andromeda* [= *Pieris*] *floribunda*. A compact evergreen shrub............................ 2 to 3 feet

(w) *Lonicera canadensis* and *L. cærulea*. Small shrubs. 4 to 5 feet

**Lonicera fragrantissima*. A spreading shrub. Semi-evergreen. (See page 831.)................. 6 feet

Magnolia conspicua [= *M. yulan*]. The finest Tree Magnolia. Bears a mass of bloom before leaves appear. From China .... To 40 feet

(w) *Prunus avium* (Sweet Cherry) in many forms, Tartarian being the best. Second week in May. A large tree.

Prunus cerasus (Sour Cherry), as May Duke and Richmond. Second week in May. A small tree.

Prunus domestica, as Lombard and Green Gage Plums. A small tree.

Early May (*continued*)			Height
White	(w)	*Prunus nigra* (Canada Plum). Flowers pinkish as they fade. A small tree	15 feet
	(w)	*Prunus pennsylvanica* (Bird Cherry, or Wild Red Cherry)	To 25 feet
		Prunus persica var. *flore pleno alba* (Double White Peach). A small tree	To 15 feet
		Prunus tomentosa. A wide-spreading shrub. About a week ahead of *P. pendula*	6 to 8 feet
		Prunus triflora (Chinese Plum). A small tree. The Japanese plums have developed from this type	15 feet
		Spiræa arguta. A graceful shrub, similar to **S. thunbergii* but more vigorous and hardy and with broader foliage	4 to 5 feet
		**Spiræa prunifolia* var. *flore pleno* (Bridal Wreath). (See page 832.)	6 feet
		**Spiræa thunbergii.* (See page 829.)	
		Syringa affinis. A new Chinese Lilac, blooming as early as the lavender *S. oblata.* Buds are not injured by the cold	10 to 15 feet
	(w)	*Vaccinium pennsylvanicum* (Early Low Blueberry.) (See page 853.)	6 to 12 inches
Yellow		*Acer platanoides* (Norway Maple). An excellent street tree. (See page 815.)	
	(w)	*Acer saccharum* (Sugar Maple). Flowers greenish yellow, pendulous on long stems, appearing about a week later than those of Norway Maple.	
		**Berberis thunbergii* (Japanese Barberry). A beautiful shrub at all times. (See page 827.)	4 to 6 feet
		**Lonicera fragrantissima.* Flowers white or pale yellow, foliage semi-evergreen. (See page 831.)	
		Mahonia aquifolium (Oregon Grape). (See page 818.)	2 to 4 feet
		Mahonia repens. The hardiest Mahonia. (See page 818.)	1 foot
	(w)*	*Rhus canadensis* [= *R. aromatica*]. Low and spreading. (See page 828.)	3 feet
	(w)	*Ribes aureum* (Missouri, or Buffalo, Currant). Now called *R. odoratum*	4 to 5 feet
Orange		**Cydonia* [= *Pyrus*, or *Chænomeles*] *japonica* (Japanese Quince). (See page 827, and *Hedge Plants*, page 817.)	4 to 6 feet
		Cydonia [= *Pyrus*, or *Chænomeles*] *maulei.* Resembles the *Japanese Quince (*C. japonica*), but is low and spreading. All the Cydonias are liable to be infested with San José scale	2 to 3 feet
Red		*Prunus persica* var. *flore pleno rubra* (Double Red Peach). A small tree	To 15 feet
Pink		*Daphne cneorum* (Garland Flower). Compact, evergreen. (See under *Low Woody Plants for Rock Garden or Small Edging*, page 854.)	6 to 12 inches
		Magnolia alexandrina. Light pink	10 to 15 feet
		Magnolia soulangeana. Tinged rose	10 to 15 feet
		Prunus persica (Orchard Peach). Second week in May	15 feet
		Prunus sargentii (Japanese Cherry). Rosy pink, an excellent species. A small tree, new in commerce	30 feet
		**Prunus triloba* var. *flore pleno* (Flowering Almond). (See page 831.)	5 to 6 feet
	(w)	*Rhododendron* [= *Azalea*] *vaseyi.* Light pink	5 to 8 feet

		Height
Early May (*continued*)		
Lavender or pale purple	*Prunus pendula* (Weeping Japanese Cherry). A small tree, which, like Flowering Almond, is covered with a mass of bloom before the leaves appear, the second week in May. Weeping habit.	15 feet
	Syringa oblata. One of the first Lilacs to bloom, but the buds are often injured by cold. The plant is of value for its dark, leathery foliage, which turns a rich crimson in fall..................	10 to 15 feet
Rosy purple	(w) **Cercis canadensis* (Redbud, or Judas Tree). A small, spreading tree. (See page 832.)........	20 feet
	(w) *Rhododendron canadense* (Rhodora). (See page 853.)....................................	2 feet
Middle May.....	The *Flowering Dogwood (*Cornus florida*) is blooming now, both the white type and the beautiful pink variety *rubra*. Also Apples, Pears, Native Plums, and German Prunes (a form of *Prunus domestica*), early-flowering Crab Apples (**Pyrus floribunda*, *P. spectabilis*, *P. baccata*, and *P. halliana* [= *P. parkmanii*], the Parkman Crab), the brilliant *Japanese Azalea (*Rhododendron* [= *Azalea*] *kæmpferi*), the Blue Myrtle, or Periwinkle (*Vinca minor*), and the beautiful white and lavender Wistarias.	
White.....	(w) *Amelanchier sanguinea*. A small, shrubby Amelanchier, with large flowers appearing two weeks later than those of *A. canadensis* and *A. lævis*.	
	(w) **Cornus florida* (Flowering Dogwood). A small tree. (See page 833.)......................	20 feet
	(w) *Dendrium* [= *Leiophyllum*] *buxifolium* (Sand Myrtle). A dense evergreen shrub. Var. *prostratum* is a lower form. (See under *Low Woody Plants for Rock Garden or Small Edging*, page 854.)................................	To 3 feet
	(w) *Prunus americana* (Plum) in variety, as Wyant and Forest Garden. May 12 to 20. Small trees..	15 feet
	Prunus domestica (Plum), German Prune variety.	15 feet
	(w) *Prunus hortulana* (Plum) in variety, as Golden Beauty and Wayland. May 15 to 24........	15 feet
	(w) *Prunus maritima* (Beach Plum). A straggling, thorny bush, with abundant early bloom.....	3 to 5 feet
	(w) *Prunus munsoniana* (Wild Goose Plum). May 13 to 25..................................	15 feet
	(w) *Prunus virginiana* (Chokecherry). A small tree or shrub............................	To 15 feet
	Pyrus baccata (Siberian Crab). Flowers white. Tree often as large as the common Apple.....	20 to 30 feet
	Pyrus communis (Orchard Pear)...............	20 to 30 feet
	Pyrus malus (Orchard Apple).................	20 to 30 feet
	Pyrus salicifolia. From Siberia. Has narrow silvery leaves. A small tree................	15 feet
	Pyrus simonii. A Chinese variety. This is the earliest and most ornamental pear. It has large, abundant flowers, and thick, shining foliage which turns a bright red in the fall. A tree..................................	To 30 feet
	Pyrus sinensis (Chinese Pear). Grows vigorously. Has large flowers and leaves. The well-known Kieffer Pear is a hybrid between the Chinese Pear (*P. sinensis*) and the European Pear (*P. communis*)................................	40 feet
	**Rhodotypos kerrioides* (White Kerria)...........	6 feet

Middle May (*continued*)		Height
White	*Ribes cereum*. A small shrub from the Northwest. Has small, attractive leaves which show green very early	3 to 4 feet
	(w) *Sambucus racemosa* (Red Elderberry). This is in red fruit when the Common Black Elderberry (*S. canadensis*) is in white flower. It is commoner in woodland shade than *S. canadensis*, and under these conditions it is more loose and spreading in habit	6 to 8 feet
	(w) *Viburnum alnifolia* [= *V. lantanoides*] (Hobblebush).	
	Viburnum carlesii. A new shrub from Korea. The buds are red, changing through pink to white as the flowers open	6 feet
	Viburnum lantana (European Wayfaring Tree). A large, vigorous shrub, with heavy, wrinkled foliage	10 to 15 feet
Yellow	**Kerria japonica* (Globeflower). Has single or double flowers. (See page 827.)	4 to 5 feet
	(w) *Salix alba* (White Willow). Escaped from cultivation. A large tree.	
Orange	*Ribes pinetorum*. Flowers orange-red. From mountains of Arizona and New Mexico	3 to 4 feet
Red	*Magnolia lennei*. Flowers crimson	10 to 15 feet
	**Rhododendron* [= *Azalea*] *kæmpferi* (Japanese Azalea)	5 to 8 feet
Rosy pink	*Pyrus halliana* [= *P. parkmanii*] (Parkman Crab). A large, graceful shrub or small tree	20 feet
	(For the native eastern Crab Apple and also Bechtel's Double-flowering Crab, see under *Late May, Pink*, page 842.)	
Pink	**Cornus florida* var. *rubra* (Pink Dogwood). A small tree	20 feet
	**Pyrus floribunda* (Flowering Crab). A small, spreading tree, blooming about the second week in May, preceding the Parkman Crab	10 to 15 feet
	Pyrus spectabilis (Chinese Crab). Flowers light pink, in both single and double varieties. A small tree	To 15 feet
Blue	*Vinca minor* (Myrtle, or Periwinkle). A hardy trailing evergreen, excellent for ground cover, especially in the shade.	
Late May	*Garden Lilacs in many colors (varieties of *Syringa vulgaris*) are now at their best (during the third and fourth weeks of May), to be accompanied or followed closely by the very graceful and handsome *Rouen Lilac (*S. chinensis* [= *S. rothomagensis*]). (See page 835, under *S. vulgaris*.) Tree Peonies (*Pæonia moutan*) are making a great display now, with magnificent single or semi-double flowers in many colors. These are woody Peonies from 2 to 5 feet high, from China, and are the earliest of all the Peonies to bloom. They are more difficult to grow than herbaceous Peonies. Bush Honeysuckles (**Lonicera tatarica*, *L. morrowii*, and their varieties) are in bloom at the same time; also, * *Spiræa vanhouttei* for white, * *Berberis vulgaris* and *Caragana frutescens* for yellow, and *Rhododendron carolinianum*, Eastern Crab Apple	

Late May (*continued*)		Height
	(*Pyrus coronaria*) and *Bechtel's Crab (*Pyrus ioensis* var. *bechtelii*), and *Rhododendron* [= *Azalea*] *nudiflora* for pink. The Horse-chestnut and the red Buckeye are also in bloom by the last of May, also the Cinnamon Rose (*Rosa cinnamomea*), which is the earliest of the Roses.	
White.........	*Æsculus hippocastanum* (Horse-chestnut). Flowers tinged with red. A large tree.	
(w)*	*Aronia* [= *Pyrus*] *arbutifolia*. Has beautiful red berries. (See page 827).................	4 to 6 feet
(w)	*Aronia* [= *Pyrus*] *nigra*......................	4 to 6 feet
	Chionanthus retusa (Chinese Fringe Tree). Blooms from a week to ten days earlier than **C. virginica*. Flowers in short, erect, nodding clusters, bark on older twigs exfoliating (peeling off).	
(w)	*Cornus alternifolia*..........................	To 20 feet
(w)*	*Cornus stolonifera* (Red Osier Dogwood). A spreading shrub.........................	6 feet
(w)	*Cratægus arkansana*.........................	15 feet
(w)	*Cratægus coccinea*...........................	15 feet
(w)	*Cratægus oxyacantha*. (English Hawthorn)......	15 to 20 feet
(w)	*Cratægus punctata*. Has a very picturesque horizontal branching, like **C. crus-galli*........	15 to 20 feet
	Cydonia [= *Pyrus*, or *Chænomeles*] *vulgaris* (Common Quince). A shrub or small tree.	
	Deutzia gracilis............................	2 to 3 feet
	Deutzia lemoinei. A better hybrid of the preceding species..............................	3 to 4 feet
	Exochorda grandiflora (Pearlbush).............	6 to 8 feet
	Halesia carolina [= *H. tetraptera*] (Snowdrop Tree, or Opossum Wood). A large shrub or small tree..................................	To 20 feet
(w)	*Leucothoë catesbæi*. Has large leaves, dark and evergreen. An arching shrub...............	2 to 3 feet
	Lonicera bella (a hybrid between **L. tatarica* and *L. morrowii*). Flowers often tinged pink. A large, upright shrub.......................	8 to 10 feet
	Lonicera morrowii. Flowers tinged with or fading to yellow. A broad-spreading shrub. (See page 826.)...............................	6 feet
(w)*	*Lonicera tatarica* (Tartarian Honeysuckle). Flowers often tinged with pink but never with yellow. The common Bush Honeysuckle. A tall, upright shrub, with perfectly smooth leaves and twigs. (See page 834.)...........	8 to 10 feet
	Spiræa cantoniensis [= *S. reevesiana*]. One of the parents of **S. vanhouttei*..................	4 feet
	Spiræa trilobata. The other parent of **S. vanhouttei*. A slender shrub..................	To 4 feet
	**Spiræa vanhouttei*. (See page 832.)..............	6 feet
	**Syringa chinensis* [= *S. rothomagensis*] var. *alba* (Rouen Lilac). (See under *S. vulgaris*, page 835.)	10 to 12 feet
	**Syringa persica* var. *alba* (Persian Lilac). Resembles its hybrid, the *Rouen Lilac mentioned above, but is not so large, handsome, or vigorous. (See under *S. vulgaris*, page 835.)......	6 to 8 feet
(w)	*Vaccinium corymbosum* (High Bush Blueberry). (See page 821.)...........................	5 to 8 feet
	Viburnum opulus var. *sterilis* (Common Snowball).	10 to 12 feet
(w)*	*Viburnum prunifolium* (Black Haw). A bushy tree. (See under *V. lentago*, page 835.).......	10 to 15 feet
	Viburnum tomentosum. A spreading, flat-topped shrub.................................	6 to 8 feet

Late May (*continued*)		Height
White	*Viburnum wrightii*. This and **V. opulus* (High Bush Cranberry) are the best red-berried Vibernums. An upright shrub. Similar to *V. dilitatum*, but has larger fruit and handsome glossy foliage.	8 to 10 feet
	Wisteria chinensis var. *alba* (Wistaria). (See under *Flowering Vines*, page 851, and under *Lavender* below.)	
Yellow	(w) *Æsculus glabra* (Ohio Buckeye). Flowers greenish yellow. A small tree	30 feet
	(w) *Æsculus octandra*. A large tree	40 to 60 feet
	(w) **Berberis vulgaris* (Common Barberry)	6 to 8 feet
	Caragana frutescens (Pea Tree)	6 to 8 feet
	Laburnum vulgare (Golden Chain). A small tree. (See *L. alpinum*, page 833.)	To 20 feet
	Lonicera morrowii. (See under *White*.)	
	(w) *Magnolia acuminata* (Cucumber Tree). Flowers greenish yellow. A large tree.	
Red	*Æsculus carnea* [= *Æs. rubicunda*] var. *briotii*. The best red Buckeye. Flowers scarlet. A small, compact tree	30 feet
	**Cratægus oxyacantha* var. *paulii* (Paul's Double Red Thorn). (See page 833.)	15 to 20 feet
	Rhododendron [= *Azalea*] *hinodegira*. A low evergreen shrub. (See page 854.)	
Pink	*Lonicera bella* var. *rosea*. An excellent hybrid of **L. tatarica*	8 to 10 feet
	Lonicera spinosa [= *L. albertii*]. (See page 853.)	1 to 2 feet
	Lonicera tatarica var. *splendens*	10 to 15 feet
	(w) *Pyrus coronaria*. (Eastern Crab Apple.) Flowers single, pink	20 feet
	**Pyrus ioensis* var. *bechtelii* (Bechtel's Crab). (See page 834.)	15 to 20 feet
	(w) *Rhododendron carolinianum* [= *R. punctatum* in part]. The best early evergreen Rhododendron. Low and evergreen. (See index.)	3 to 5 feet
	(w) *Rhododendron* [= *Azalea*] *nudiflora* (Pinkster Flower, or Wild Honeysuckle)	3 to 5 feet
Rosy lavender	*Rosa cinnamomea* (Cinnamon Rose). The earliest Rose	5 to 6 feet
	**Syringa chinensis* [= *S. rothomagensis*] var. *rubra* (Rouen Lilac). (See under *S. vulgaris*, page 835.)	10 to 12 feet
	**Syringa persica* var. *rubra* (Persian Lilac). (See under *S. vulgaris*, page 835.)	6 to 10 feet
Lavender	*Wisteria chinensis* (Wistaria). This sometimes does not bloom until early June, and sometimes not at all. In the latter case the roots should be pruned in spring by digging a trench around the plant, three feet out from the stem if the plant is a large one, and two feet deep in order to cut all the roots. The trench should be refilled with poor, rather than rich, soil, having mixed with it some phosphoric acid fertilizer such as bone meal or acid phosphate. Phosphorus stimulates the growth of flowers and fruit. The top should be pruned back rather heavily. The following spring some flowers should appear. After the flowering is over and just as leaf growth is beginning, the top should be pruned again. The second spring the plant should flower normally. (See under *Flowering Vines*, page 851.)	

		Height
Late May (*continued*)		
Blue-lavender..	*_Syringa chinensis_ [= _S. rothomagensis_]) (Rouen Lilac). (See under _S. vulgaris_, page 835.)....	12 feet
Early June......	Many-colored *Diervillas begin to blossom in early June (see page 830); also hybrid Rhododendrons in great variety, from early to middle June. (See _**Rhododendrons**_, page 818.) Other plants in bloom at this time are the Rose Acacia (_**Robinia hispida**_), the * White Fringe (_**Chionanthus virginica**_), the *Scotch Laburnum (_**Laburnum alpinum**_), which is yellow, the *Scotch Rose (_**Rosa spinosissima**_), Harrison's Yellow Rose, the *Japanese Rose (_R. **rugosa**_), the * Cockspur Thorn (_Cratægus crus-galli_), the * Flame Azalea (_**Rhododendron**_ [= _Azalea_] _**calendulaceum**_), and the last of the Shrubby Lilacs (_Syringa **villosa**_).	
White.....	(w) _Andromeda_ [= _**Pieris**_, or _Lyonia_] _**mariana**_ (Staggerbush).............................	2 to 3 feet
	(w)*_**Chionanthus virginica**_ (Fringe Tree). A large shrub or small tree.........................	To 30 feet
	Cornus alba. The commonest cultivated red-stemmed Dogwood. More upright than *_C. stolonifera_ (Red Osier Dogwood).............	8 to 10 feet
	(w) _Cornus circinata_ [= _C. rugosa_] (Round-leaved Dogwood). Has the best foliage of the shrubby Dogwoods. One-year twigs with brown dashes.	6 feet
	(w)*_Cratægus crus-galli_ (Cockspur Thorn). (A small tree, with horizontal branches and very long thorns. (See page 833.)....................	15 to 20 feet
	(w) _Cratægus nitida_. A small tree.................	15 feet
	(w) _Cratægus tomentosa_. A small tree..............	15 feet
	(w) _Prunus serotina_ (Wild Black Cherry). A large tree..................................	To 80 feet
	*_Rosa rugosa_ var. _alba_. A Japanese Rose. Very hardy and desirable. Blooms throughout June. (See page 828.)...........................	3 to 5 feet
	*_Rosa spinosissima_ var. _altaica_ (Altai Rose.) Siberian form of the Scotch Rose. A very dainty Rose. (See under _R. spinosissima_, page 828.)..	2 to 3 feet
	(w) _Sorbus americana_ (American Mountain Ash). A small tree..................................	20 to 30 feet
	Sorbus aucuparia (European Mountain Ash).....	30 to 40 feet
	Spiræa bracteata. This begins to bloom about the second week in June, after *_S. vanhouttei_. Has excellent dark glossy foliage and very picturesque winter form. (See under _Deciduous Shrubs for Foliage_, page 826.)	
	(w)* _Viburnum lentago_ (Nannyberry). (See under _Deciduous Shrubs for Foliage_, page 826, and page 835.) A large shrub or small tree.......	To 20 feet
	(w)* _Viburnum opulus_ (High Bush Cranberry). (See page 835.)	
	Viburnum plicatum [=_V. tomentosum_ var. _dilitatum_] (Japanese Snowball). Better than the Common Snowball (_V. opulus_ var. _sterilis_). Has good flowers and handsome glossy foliage.....	6 to 8 feet
	(w) _Viburnum pubescens_..........................	4 to 5 feet
	Viburnum sieboldii. Has large, wedge-shaped leaves, with a strong odor when crushed. A large shrub or small tree........................	20 to 30 feet

Early June (*continued*)		Height
Yellow	**Laburnum alpinum* (Scotch Laburnum). (See page 833.)	20 to 30 feet
	(w)**Rhododendron* [= *Azalea*] *calendulaceum* (Flame Azalea). (Also orange.) (See page 831.)	5 to 8 feet
	(w) *Rhus typhina* [= *R. hirta*] (Staghorn Sumac). (See under *Deciduous Shrubs for Foliage*, page 826.)	20 feet
	Rosa harrisonii (Harrison's Yellow Rose). (See page 820.)	
Orange....	(w)**Rhododendron* [= *Azalea*] *calendulaceum* (Flame Azalea). (See page 831.)	5 to 8 feet
Red..........	**Rosa rugosa*. Blooms throughout June. (See page 828.)	3 to 5 feet
Pink.........	**Diervilla hybrida*, Le Printemps variety. (See page 830)	6 to 8 feet
	(w) *Robinia hispida* (Rose Acacia)	4 to 5 feet
	(w) *Rosa blanda*. The earliest of our small native Roses	4 to 6 feet
	Rosa hibernica var. *gravesii*. Flowers a delicate shell pink. A hybrid of **R. spinosissima* and *R. canina*	2 to 3 feet
	**Rosa rugosa*. (See page 828.)	3 to 5 feet
Lavender......	*Syringa villosa*. A bushy shrub, the last of the shrubby Lilacs	6 to 8 feet
Middle June....	Roses—especially the rambler rose *Tausendschön and the shrubby * Japanese Rose (*Rosa multiflora*)— the old sweet-scented *Syringa, or Mock Orange (*Philadelphus coronarius*), Viburnums, Mountain Laurels (Kalmia), and Japanese Honeysuckle (*Lonicera japonica*), are the dominant flowers in the middle of June. The Common, or Black, Locust (*Robinia pseudacacia*) and the *Yellowwood (*Cladrastis lutea* [= *C. tinctoria*]) both begin blooming now. The beautiful semi-evergreen Sweet Bay (*Magnolia glauca* [= *M. virginiana*]) will also continue to open its fragrant white flowers until the middle of July. Moneywort, or Creeping Charlie (*Lysimachia nummularia*), has yellow bloom in June and early July.	
White.....	(w)**Cladrastis lutea* [= *C. tinctoria*] (Yellowwood). (See page 832.)	30 to 40 feet
	(w)**Cornus paniculata* [= *C. candidissima*]. (See page 829.)	5 to 8 feet
	(w) *Kalmia latifolia* (Mountain Laurel). The best broad-leaved evergreen shrub. Flowers white to pink. Old plants sometimes 15 feet high. (See page 818.)	5 to 8 feet
	(w) *Lonicera japonica* (Japanese Honeysuckle.) Semi-evergreen. (See under *Yellow*.)	
	(w) *Magnolia glauca* [= *M. virginiana*] (Sweet Bay). Semi-evergreen. Native as far north as Cape Cod, and becoming treelike in the South	8 to 15 feet
	(w) *Opulaster opulifolius* (Ninebark). Called also Physocarpus, or Spiræa. A coarse shrub, with characteristic shreddy bark	8 to 10 feet
	(w)**Philadelphus coronarius* (Syringa, or Mock Orange)	8 to 10 feet
	(w) *Rhododendron* [= *Azalea*] *arborescens*. Flowers white, with red stamens	8 to 10 feet
	(w) *Robinia pseudacacia* (Common, or Black, Locust). Has hanging clusters of fragrant white flowers	80 feet

		Height
Middle June (*continued*)		
White........	**Rosa multiflora*. A Japanese rose. (See page 831.)	6 feet
	Styrax japonica. A large shrub or small tree....	To 30 feet
	(w)**Viburnum acerifolium* (Maple-leaved Viburnum). (See page 829.)...........................	4 to 6 feet
	(w) *Viburnum cassinoides* (Withe-rod). Has handsome dark leaves, with wavy margins or almost entire....................................	4 to 6 feet
	(w)**Viburnum dentatum*. (See page 835.)...........	10 to 15 feet
Yellow........	*Colutea arborescens* (Bladder Senna)............	10 to 15 feet
	(w) *Liriodendron tulipifera* (Tulip Tree, or Whitewood). Has tulip-like flowers, greenish yellow with orange center. Leaves squared or with wide angled notch at the end, very characteristic. A large tree, with soft, brittle wood. (See *Bad Street Trees*, page 815, also page 816.)	
	(w) *Lonicera japonica* (Japanese Honeysuckle). Escaped from cultivation. (See page 850.) Flowers (in June and July) fragrant, fading yellow. Hall's Honeysuckle is a fall-blooming variety. Both are semi-evergreen.	
	(w) *Lysimachia nummularia* (Moneywort, or Creeping Charlie). A creeping evergreen. (See page 854.)	
Pink.....	(w) *Kalmia latifolia* (Mountain Laurel). Flowers range from white to light pink. (See *White*, above.) The best broad-leaved evergreen shrub. (See page 818).	
	(w) **Rosa lucida* (Glossy Rose). Has red stems armed with rather stout prickles....................	4 to 6 feet
	(w) *Rosa nitida*. Has red stems thickly beset with weak bristles. (See page 826.)...............	2 to 3 feet
	*Rose, Tausendschön. (See page 828.)	
Blue..........	*Sophora vicifolia*. Has an abundance of blue and white pea-shaped flowers. A new shrub.......	4 to 5 feet
Late June.......	The Common Black Elderberry (*Sambucus canadensis*) is coming into white flower everywhere, and the Red Elderberry (*Sambucus racemosa*) is in red fruit at the same time. Other plants of special note are the Crimson Rambler Rose, the Tree Lilac (*Syringa japonica*), the *Washington Thorn (*Cratægus cordata*) — the finest of all Thorns — the medium-blooming Syringas (**Philadelphus inodorus* and **P. latifolius*), two yellow-flowered and green-stemmed shrubs, Scotch Broom (*Cytisus scoparius*) and Dyer's Weed, or Woodwax (*Genista tinctoria*), and finally the *Privets, both the low, graceful Regel's Privet and the taller *ibota* and *vulgare* types.	
White....	(w) *Andromeda* [= *Zenobia*] *speciosa*. A graceful shrub. Has the largest flowers of all the Andromedas. Var. *pulverulenta* is a glaucous or blue silvery form which is handsomer than the green type. The foliage is semi-evergreen..........	3 to 4 feet
	(w) *Cornus amomum* [= *C. sericea*] (Silky, or Purple-stemmed, Dogwood). An excellent spreading shrub, but not so safe for "filler" as *C. paniculata*. (See top of page 830).................	5 to 8 feet
	(w)**Cratægus cordata* (Washington Thorn). The best of the Thorns. A small tree.................	To 30 feet

Late June (*continued*)		Height
White	*Deutzia scabra* var. *flore pleno* (Deutzia, Pride of Rochester). Habit stiff and foliage rough. Plant usually killed back and full of deadwood in spring	4 to 6 feet
	**Ligustrum ibota* (Ibota Privet). (See *L. vulgare*, page 350, and *Hedge Plants*, page 817.)	6 to 8 feet
	**Ligustrum ibota* var. *regelianum* (Regel's Privet). (See page 827.)	5 to 6 feet
	(w) **Ligustrum vulgare* (Common Privet). Semi-evergreen. Page 834, and *Hedge Plants*, page 817.)	6 to 8 feet
	(w) **Philadelphus inodorus*, **P. latifolius*, and **P. lemoinei*. (See pages 831, 834, 828.)	
	(w) *Rhododendron* [= *Azalea*] *viscosum*. (Swamp Azalea)	5 to 8 feet
	(w) *Sambucus canadensis* (Common Black Elderberry)	8 to 10 feet
	Syringa japonica (Tree Lilac). A small, round-topped, compact tree, with shining bark like a Sweet Cherry (*Prunus avium*), and large, erect, symmetrical clusters of creamy white, ill-smelling flowers	30 feet
	(w) *Viburnum venosum* (= *V. molle* as known commercially). Like * *V. dentatum*, but more vigorous, and with twigs and under surface of leaves rough pubescent	8 to 10 feet
Yellow	*Cytisus scoparius* (Scotch Broom). A half-hardy, green-stemmed shrub	5 to 8 feet
	Genista tinctoria (Woodwax, or Greenweed). A weak shrub, with green stems, both prostrate and erect, sometimes spreading over whole fields.	To 2 feet
Red	**Diervilla hybrida*, Eva Rathke variety. (See page 830.)	
	Rose, Crimson Rambler. (See Rambler Roses, under *Flowering Vines*, page 850.)	
Rosy pink	*Halimodendron argenteum* (Salt Tree). A very hardy shrub from the salt fields of Siberia. Has delicate rose-colored flowers, and graceful, silvery green foliage	6 to 10 feet
Dark purple	(w) *Amorpha fruticosa* (Bastard Indigo). Has compound feathery foliage. A large shrub	10 to 15 feet
Early July	Chestnuts and Hardy Catalpas are now the dominant features in the landscape. The Lindens and the Basswoods (Tilia), the Sorbarias, the summer-blooming Spiræas (**S. japonica* and **S. salicifolia*), many of the newer Rambler Roses (largely *wichuraiana* hybrids), the New Jersey Tea (*Ceanothus americanus*) in dry fields and woods, and Jackman's Clematis (*Clematis jackmanii*) in both purple and white varieties, are also blooming throughout July.	
White	(w) *Castanea americana* (Chestnut). A broad, spreading tree.	
	(w) *Catalpa speciosa* (Hardy Catalpa). A coarse tree type, rapid-growing but weak-wooded and not hardy in the northern part of the State.	
	(w) *Ceanothus americanus* (New Jersey Tea)	2 to 3 feet
	Clematis jackmanii var. *alba* (See *Flowering Vines*, page 850.)	

Early July (*continued*)		Height
White	*Philadelphus insignis*. Large, handsome, and late-blooming. An old hybrid, sometimes called "Souvenir de Billard."	10 to 15 feet
	(w) *Sorbaria sorbifolia*	3 to 4 feet
	(w) **Spiræa salicifolia* [= *S. alba*] (Queen of the Meadow). (See *S. billardii*, page 832.)	3 to 5 feet
	(w) *Tilia americana* (American Basswood). Flowers creamy white. Blooms a week later than the European Lindens (*T. platyphyllos* and *T. vulgaris*) mentioned below	80 feet
	Tilia petiolaris (Weeping Silver Linden). The best Linden for specimen planting	50 feet
	Tilia platyphyllos and *T. vulgaris*. Both of these are known commercially as *Tilia europæa* (European Linden)	80 feet
Yellow	*Cytisus nigricans*. The best hardy Cytisus	2 to 3 feet
	(w) *Hypericum buckleii*. The earliest Hypericum, forming neat, compact mats. Native in the South	1 foot
	(w) *Potentilla fruticosa*. A low, much-branched shrub, with peculiar shreddy bark	1 to 3 feet
Orange and red.	*Lonicera heckrottii*. (See *Flowering Vines*, page 850.)	
Pink	(w) *Rosa carolina* (Swamp Rose). The last of our native Roses	6 to 8 feet
	(w) *Rubus odoratus* (Flowering Raspberry, or Thimbleberry). A slender but vigorous shrub, with very shreddy bark and large, lobed leaves. Young stems sticky-hairy. Plant good in moist shade	4 to 6 feet
	**Spiræa japonica* [= *S. callosa*]. (See page 829.)	4 feet
	**Spiræa salicifolia*. (See *S. billardii*, page 832.)	3 to 5 feet
Lavender	**Amorpha canescens* (Lead Plant). From the Middle West. A very beautiful plant, with silvery stems and leaves, and slender spikes of small lavender flowers	3 to 4 feet
Purple	*Clematis jackmanii*. (See *Flowering Vines*, page 850.)	

Middle July..... The red Trumpet Creeper (*Tecoma* [= *Bignonia*] *radicans*) and the white Memorial Rose (*Rosa wichuraiana*) are in full bloom now, and the native pink *Prairie, or Michigan, Rose is just beginning. The *Hills of Snow Hydrangea (*Hydrangea arborescens* var. *sterilis*) is in white flower, and the *Varnish Tree (*Koelreuteria paniculata*) is in conspicuous yellow flower. The *Smoke Bush (*Rhus cotinus*), the white **Sorbaria aitchinsonii*, the pink **Spiræa douglasii*, and the *Dwarf Buckeye (*Æsculus parviflora*, sometimes called *Pavia macrostachya*), are noticeable at this time. Scotch Heather (*Calluna vulgaris*) also blooms during July and August. This has escaped from cultivation and become established in both Massachusetts and Nova Scotia.

White	(w) **Æsculus parviflora* (Dwarf Buckeye). (See page 829.)	5 to 8 feet
	(w) **Hydrangea arborescens* var. *sterilis* (Hills of Snow). (See page 830.)	5 to 8 feet
	(w) *Hydrangea radiata*	5 to 8 feet

Middle July (*continued*)			**Height**
White.........		*Ligustrum ovalifolium* (California Privet). This kills back so much that it seldom flowers or fruits in the North. The flowers are creamy white and the fruit black and shining, in terminal clusters like those of the similar but hardy **Ligustrum vulgare*.	
		Rosa wichuraiana (Memorial Rose). Has continuous white blooms throughout July. (See *Low Woody Plants for Ground Cover*, page 852, and under *Rambler Roses*, page 851.)	
		**Sorbaria* [= *Spiræa*] *aitchinsonii*. Better than *Sorb. sorbifolia*, and a great addition to summer-blooming Spiræas such as **Spiræa salicifolia* [= *S. alba*] and **S. japonica* [= *S. callosa*].....	6 feet
	(w)	**Symphoricarpos racemosus* (Snowberry). (See page 829.)	4 to 6 feet
		Yucca filamentosa (Adam's Needle). A hardy evergreen, with underground stems, and long, sword-shaped, sharply pointed leaves in low, rosette-like clusters. Curly fibers on leaf margins, flowers in large cluster on long, upright stem.	
Pink.....	(w)	*Calluna vulgaris* (Scotch Heather). Evergreen. (See *Low Woody Plants for Rock Garden or Small Edging*, page 853.)	2 to 3 feet
		Indigofera kerilowii. Kills down, but springs up vigorously. Flowers small, pealike...........	2 to 3 feet
	(w)	*Phyllodoce* [= *Bryanthus*] *cœrulea* (Mountain Heath). Evergreen. An alpine shrub. (See under *Low Woody Plants for Rock Garden or Small Edging*, page 854.).................	3 to 6 inches
	(w)	**Rosa setigera* (Prairie, or Michigan, Rose). (See page 828.)	4 to 6 feet
		**Spiræa billardii*. (See page 832.)	5 to 6 feet
		**Spiræa douglasii*. A vigorous plant from the Northwest. Like **S. tomentosa*, but larger and earlier in bloom. (See *S. billardii*, page 832.) .	6 to 8 feet
Rosy purple..		**Rhus cotinus* (Smoke Bush). (See page 834.)	10 to 15 feet
Late July.......		Hypericums, Summer Lilac (*Buddleia variabilis* [=*B. davidii*]), Sweet Pepper Bush (*Clethra alnifolia*), the little red **Spiræa bumalda*, Anthony Waterer variety, and the white **Spiræa albiflora*, become interesting now and continue into August.	
White....	(w)	*Clethra alnifolia* (Sweet Pepper Bush). Flowers in narrow, upright spikes. Is best planted in moist soil..............................	5 to 8 feet
		Hydrangea paniculata var. *præcox*. This is an early-flowering form of the single wild Hydrangea of China and Japan (**H. paniculata*), a late-flowering type from which has been developed the common double late-flowering *Hardy Hydrangea (*H. paniculata* var. *grandiflora*, described on page 833)	10 to 15 feet
	(w)	*Oxydendrum arboreum* (Sorrel Tree, or Tree Andromeda). A very graceful, small tree, with nodding clusters of creamy white flowers against a rich, glossy foliage turning orange and red in the fall..................................	30 feet
		**Spiræa albiflora*. (See page 828.) Dense and compact	18 inches

Late July (*continued*) Height

Yellow..... (w)**Hypericum aureum*. (See page 827.)............ 3 feet
(w)**Hypericum prolificum*. (See page 827.).......... 3 feet

Red..........**Spiræa bumalda*, Anthony Waterer variety. (See page 828.)................................... 2 feet

Blue..........**Buddleia variabilis* [=*B. davidii*] var. *magnifica* (Summer Lilac). (See page 827.)............ 4 to 5 feet

August......... The *Hardy Hydrangea, white, both single and double, the old-fashioned *Rose of Sharon (*Hibiscus syriacus*) in several colors — white, pink, blue, and purple — the *Steeplebush, or Hardhack (*Spiræa tomentosa*), and the inconspicuous flowers of *Coralberry (*Symphoricarpos vulgaris*), bloom in August. *Lonicera heckrottii*, the Hybrid Honeysuckle already mentioned as blooming in July and described under *Flowering Vines* (page 850), is blooming profusely and continuously, and the Japanese Pagoda Tree (*Sophora japonica*) has long, hanging clusters of yellowish white flowers at this time. *Vitex incisa* also blooms throughout August. This is a strongly aromatic shrub from 6 to 8 feet high, with light, delicate foliage, and lavender-colored flowers in terminal pyramidal clusters. The leaves are digitately compound, like a horse-chestnut leaf, with deeply cut leaflets, grayish hairy below.

September... (w) *Ampelopsis quinquefolia* (Virginia Creeper), now called *Parthenocissus quinquefolia*. Is in beautiful autumn color at this time, and makes a fine combination with the Japanese Clematis.
(w) *Baccharis halimifolia*. A shrub now covered with its fluffy, hairy fruit, which resembles a mass of white flowers............................ 4 to 8 feet
The Japanese Clematis (*Clematis paniculata*) is the most conspicuous plant in flower during September and October. (See *Flowering Vines*, page 850.)

October.... (w)**Hamamelis virginiana*. (See page 833.)........ 10 to 15 feet

VINES

Vines for Brick and Stone

Deciduous (Climb by tendrils ending in disks)
Boston Ivy (*Ampelopsis veitchii* [= *A. tricuspidata*], now called *Parthenocissus tricuspidata*).

Evergreen (Climb by rootlike holdfasts)
English Ivy (*Hedera helix*). Somewhat tender. Best on north or east side of house, where it is protected from the winter sunlight.
Evonymus radicans. Hardier than English Ivy. The variety *vegeta*, with broad, round leaves, is the best. Is doubly attractive when care is taken to get fruiting forms that give a fine contrast of orange and red berries with dark green foliage.

Vines for Foliage

NOTE.— *Evonymus radicans*, *Hedera helix*, and *Vinca minor* are good evergreen vines. *Lonicera japonica* var. *halliana* is semi-evergreen, holding good foliage until Christmas. *Forsythia suspensa*, *Tecoma* [= *Bignonia*] *radicans*, and (especially) *Wisteria chinensis*, also have good foliage, but are classed as flowering vines.

Virginia Creeper (*Ampelopsis quinquefolia*, now called *Parthenocissus quinquefolia*). Climbs by tendrils. The first vine to color in the fall. Foliage beautiful scarlet and red.

Climbing Bittersweet (*Celastrus scandens*). Climbs by twining. Berries red and orange all winter.
Akebia quinata. A twining vine from China and Japan, with delicate foliage, five-parted like that of Virginia Creeper, but smooth and firm and nearly evergreen, remaining until January. One of the most graceful foliage vines on the market.
Crimson Glory Vine (*Vitis coignetiæ*). From Japan. A large, vigorous grapevine, with immense, leathery leaves which are usually brown felty beneath. The foliage is especially strong and bold, turning scarlet and crimson in the fall. The handsomest of all grapevines.
Actinidia arguta. From China. Climbs by twining; vigorous in growth. Foliage dark and glossy. The best vine for covering an arbor.
Japanese Honeysuckle (*Lonicera japonica*). Climbs by twining. Flowers small, white to yellow, very abundant and fragrant in June and July. Foliage semi-evergreen, remaining until January. A handsome porch plant, but also very useful for covering banks. Hall's Honeysuckle is a fall-blooming variety.
Dutchman's Pipe (*Aristolochia macrophylla* [= *A. sipho*]. A vigorous twiner, climbing high. Stems often from one to two inches thick. Leaves large, broad oval, casting very dense shade. Should not be used unless heavy shade is desired.
Matrimony Vine (*Lycium halimifolium* [= *L. vulgare*]). Has grayish green, semi-evergreen foliage, and soft, bright, red berries in late summer. A rank-growing shrub, with recurving branches, well adapted to covering banks. The Chinese Matrimony Vine (*L. chinense*) is similar, but is better because it is larger in every part, with foliage light green, not gray-green like that of *L. halimifolium*. (See *Rapid-growing Vines for Quick Effects*, page 851.)
Common Greenbrier (*Smilax rotundifolia*). A vigorous wild vine, with fine, glossy foliage enduring both shade and wet soil.

Flowering Vines

Clematis jackmanii. Climbs by twisting leaf stems. Flowers large and purple. *C. jackmanii* var. *alba* is similar, but the flowers are creamy white. Both of these are good vines for bloom in July and August.
Japanese Clematis (*Clematis paniculata*). Climbs as does the preceding species. Flowers small and white, covering plant with a mass of bloom in September and October. Foliage remains glossy green, good until December. The best fall-blooming vine.
Golden Bell (*Forsythia suspensa*). From China. A graceful, shrub, with recurving and trailing branches. Excellent for hanging over a bank or down a wall. Flowers yellow, appearing before the leaves, covering the plant with a mass of bloom in April. Flower buds often killed by cold in the northern part of the State.
Japanese Honeysuckle (*Lonicera japonica*). Bloom profuse and fragrant; flowers white, fading yellow in June and July. Hall's Honeysuckle is a fall-blooming variety.
Lonicera heckrottii. Climbs by twining. This is a hybrid which blooms continuously during July, August, and September. The flowers are rose outside and yellow inside, and as open and closed flowers are present at the same time they make a very handsome showing. The only objection to the plant is that it is badly infested with aphids, or green flies.
Rambler Roses (in order of bloom, June and July). These must be tied up, but are hardy without protection except possibly in the northern part of the State. In such cold places one must be content with the upright shrubby *Rosa rugosa* (in white, pink, and red varieties, both single and double), beginning in early June; with the white *Rosa multiflora*, beginning from middle to late June; and with the pink Prairie, or Michigan, Rose (*Rosa setigera*), which does not begin until the second week in July. *R. multiflora* and *R. setigera* are both shrubs with an arching habit and have produced many Rambler Roses. (See *A Selected List of Seventy-five Deciduous Shrubs*, pages 831, 828.) Of the varieties following, those marked with an asterisk are the best. *Tausendschön (middle June), double, delicate pink, larger than Dorothy Perkins. Lady Duncan, single, rich salmon-pink. *Excelsa, (late June or early July), a long-season rose, double, rich crimson; a new variety, blooming at the same season as the old Crimson Rambler, but a better color. Dorothy Perkins (early July), double pink. White Dorothy Perkins, a white variety of the preceding. Alberic Barbier (middle July), semi-double or double,

creamy white, yellow in center, dark yellow in bud; excellent glossy foliage. Aviator Bleriot is a new variety, very similar to Alberic Barbier. *Hiawatha (middle July), a long-season rose, single, bright red with white center and yellow stamens. *Mrs. H. M. Walsh (middle July), double, white; same long season and good foliage as *Rosa wichuraiana*, the Memorial Rose, of which it is practically a double form. *R. wichuraiana*, which is blooming at this time, is the parent of many of the varieties named above, and is itself a very attractive rose. (See *Low Woody Plants for Ground Cover*, page 852.)

Trumpet Creeper (*Tecoma* [= *Bignonia*] *radicans*). A heavy vine. Climbs by rootlike holdfasts, but needs strong support. Flowers red, trumpet-like, in middle July and August. Leaves opposite, compound, large, loose and feathery.

Wistaria (*Wisteria chinensis*). A strong, twining vine, with long, hanging clusters of white or purple flowers (according to variety) in middle and late May. Leaves alternate, compound, large, loose and feathery.

Rapid-growing Vines for Quick Effects

Annuals

Morning Glory (*Ipomœa purpurea*).
Moonflower (*Ipomœa bona-nox*).
Wild Cucumber (*Micrampelis* [= *Echinocystis*] *lobata*). Self-seeding.
Japanese Hop (*Humulus japonicus*).
Scarlet Runner Bean (*Phaseolus multiflorus*).
Madeira Vine (*Boussingaultia baselloides*). A tender perennial, treated as an annual, growing from 10 to 15 feet in a season. The roots must be taken up and stored away from frost. Growth rapid. Foliage thick, green. Flowers white, fragrant, in long, slender clusters. September and October.

Herbaceous Perennials (Dying down to a fleshy root)

Kudzu Vine (*Pueraria thunbergiana*). Known also commercially as *Dolichos japonicus*. Grows 40 feet in one season.

Hardy, or Perennial, Moonflower (*Ipomœa pandurata*). Foliage dense. Flowers white, with purple throat, July and August. Grows from 6 to 12 feet.

NOTE.—Both these vines have enormous fleshy roots and may become a nuisance if allowed to spread.

Perennial, or Everlasting, Pea (*Lathyrus latifolius*). A vigorous grower, from 5 to 8 feet high, with grayish green foliage and continuous bloom, either white, rose, or dark purple-red according to variety, from middle July to early September. Leaves sometimes evergreen when protected by snow.

Woody Perennials (Woody stem persisting above ground)

Japanese Honeysuckle (*Lonicera japonica*). Blooms in June and July. Hall's Honeysuckle is a fall-blooming variety.

Matrimony Vine (*Lycium halimifolium* [= *L. vulgare*]). (Also Chinese Matrimony Vine, *L. chinense*.)

Climbing Bittersweet (*Celastrus scandens*).

Actinidia arguta. A very vigorous vine, from China.

Tall-growing Vines Reaching Eaves of House

Wistaria, Climbing Bittersweet (*Celastrus scandens*), and *Actinidia arguta* are all strong, vigorous twiners. Dutchman's Pipe (*Aristolochia macrophylla* [= *A. sipho*]) is another tall-growing twiner, but it has very heavy foliage and should not be used unless dense shade is desired. Trumpet Creeper (*Tecoma* [= *Bignonia*] *radicans*) is another excellent strong-growing vine, with foliage much like that of Wistaria; it is a heavy vine and does not twine, and should be nailed to its support by leather strips.

QUICK-GROWING WOODY PLANTS FOR BANKS

Those marked with an asterisk are the best. For quick surface cover, English, or Perennial, Rye (*Lolium perenne*) should be used. (See under *Grasses for Different Purposes*, page 862.)

Vines

Climbing Bittersweet (*Celastrus scandens*).

*Japanese Honeysuckle (*Lonicera japonica*). Or its fall-blooming variety, known as *Hall's Honeysuckle.
*Matrimony Vine (*Lycium halimifolium* [= *L. vulgare*]).

Shrubs

Small (From 2 to 4 feet)
*Coralberry (*Symphoricarpos vulgaris*).

Medium (From 6 to 8 feet)
Common Barberry (*Berberis vulgaris*).
*Shrubby Dogwoods (*Cornus alba, C. stolonifera, and C. amomum* [= *C. sericea*]).
*Purple Osier (*Salix purpurea*).

Large (From 10 to 15 feet)
*Tartarian Honeysuckle (*Lonicera tatarica*).
Ninebark (*Opulaster opulifolius*, also known as Physocarpus or Spiræa).
*Common Black Elderberry (*Sambucus canadensis*).
Shrubby Willows, as Goat Willow (*Salix caprea*), Pussy Willow (*S. discolor*), and *S. cordata.*
*Staghorn Sumac (*Rhus typhina* [= *R. hirta*]).

Trees

Tree of Heaven (*Ailanthus glandulosa*), Cottonwood (*Populus deltoides*), *Common, or Black, Locust (*Robinia pseudacacia*), *White Willow (*Salix alba*), Osage Orange (*Toxylon pomiferon*, also called *Maclura aurantiaca*).

LOW WOODY PLANTS FOR GROUND COVER

Ground cover is secured most quickly by vines, but some of the low shrubs are also useful. (See *Low Perennials for Edging or Ground Cover*, page 869.)

Vines

Deciduous

Running Strawberry Bush (*Evonymus obovata*). Will endure some shade, does not twine, and comes into leaf early; for these reasons it makes good ground cover for early-blooming Azaleas.

Japanese Honeysuckle (*Lonicera japonica*). A vigorous twiner, excellent on sunny banks. Hall's Honeysuckle is a fall-blooming variety.

Matrimony Vine (*Lycium halimifolium* [= *L. vulgare*]). A vigorous, arching, shrubby vine with trailing stems, not so flat as either the Japanese or Hall's Honeysuckle.

Memorial Rose (*Rosa wichuraiana*). Distinctly low and trailing. Leaves small, glossy, and semi-evergreen. Flowers small, single, and white, in clusters, through July.

Swamp Dewberry (*Rubus hispidus*). Foliage evergreen, bronzing in winter. Stems slender and trailing.

Rubus spectabilis var. *plena* (also called *R. fruticosus* and *R. linkianus*). A handsome, vigorous, semi-evergreen blackberry from northern Europe, escaped in New England. Erect to 12 or 18 inches, with curving and long trailing stems. Leaflets large, white woolly below. Flowers white, double or semi-double.

Grape (Vitis). Many vigorous wild forms.

Evergreen

Myrtle, or Periwinkle (*Vinca minor*). A flat, trailing, vigorous plant, good in either sunlight or shade and in many kinds of soil. Very hardy. (See *Pachysandra terminalis*, in *Shrubs, Evergreen*, below.)

English Ivy (*Hedera helix*). Tenderer, but handsomer, than Myrtle. Grows best in winter shade and moist soil.

Evonymus radicans var. *vegeta.* Shrubbier and hardier than English Ivy. (See *Vines for Brick and Stone*, page 849.)

Shrubs

Deciduous

For sunlight

Roses. Wild forms, as *Rosa lucida* (4 to 6 feet) and *R. nitida* (2 to 3 feet).

Rhus canadensis [= *R. aromatica*]. A dwarf native Sumac, very vigorous and hardy. Grows from 2 to 3 feet high, with spreading, rooting stems.

Rubus cratægrifolius. A low, vigorous plant, from 3 to 4 feet high, spreading very rapidly.

Sweet Fern (*Myrica asplenifolia*). From 2 to 3 feet high. Grows in hot sunshine and dry soil.

For partly shady places

Early Low Blueberry (*Vaccinium pennsylvanicum*). Grows from 6 to 12 inches high.

Black Huckleberry (*Gaylussacia resinosa* [= *G. baccata*]). Grows from 18 inches to 2 feet high.

Yellowroot (*Xanthorhiza apiifolia*). Another hardy plant spreading vigorously and making dense cover. Grows from 18 inches to 2 feet high.

NOTE.—These three plants are native and make good woodland cover.

Evergreen

For sunlight

Common Juniper, low form (*Juniperus communis* var. *montana*). (This is also known commercially as var. *adpressa* and var. *nana*.) Low and spreading, forming broad mats 1 foot high. Foliage usually browning in winter.

Juniperus sabina var. *prostrata* (also called *J. horizontalis*). The lowest form of this is known as Waukegan's Juniper (*Juniperus horizontalis* var. *douglasii*), and is a prostrate, slow-growing Juniper, good on dry, rocky banks. Foliage steel blue, becoming more purplish in winter.

Mahonia repens. This is still comparatively unknown commercially. Native to the southern Rocky Mountains. The lowest and hardiest Mahonia, 12 inches high. Foliage bronzes in winter, but does not burn even in full sunlight.

For shade

Native Yew, or Ground Hemlock (*Taxus canadensis*).

Pachysandra terminalis. Low and spreading, only a few inches high. Leaves large, thick, and wedge-shaped, making excellent ground cover. Good in either sunlight or shade, like *Vinca minor*, but has more upright habit and larger leaves, which are a lighter, yellower green.

LOW WOODY PLANTS FOR ROCK GARDEN OR SMALL EDGING

(Arrangement is alphabetical by scientific names. See also *Rock Garden Perennials*, page 870)

Deciduous

Cotoneaster horizontalis. For edging; semi-evergreen. (See *A New Nursery List*, page 857.)

Daphne mezereum. Flowers light purple, appearing in early April before the leaves. There is a white variety. An erect shrub 3 feet high, with stout branches, which are flexible and leathery like those of Leatherwood (*Dirca palustris*).

Hypericum buckleii. Forms neat, compact mats. The earliest of the Hypericums. Flowers yellow, early July.

Lonciera spinosa [= *L. albertii*]. Has slender twigs and narrow linear leaves. Flowers pink, late May. Plant low, from 1 to 2 feet high.

Rhododendron canadense (Rhodora). A slender shrub, 2 feet high. Is good in a rock garden with a ground cover of the following species. Flowers rosy purple, appearing before the leaves in late April and early May.

Vaccinium pennsylvanicum (Early Low Blueberry). From 6 to 12 inches high. Should make good dwarf edging. Flowers white in early May.

Evergreen

Arctostaphylos uva-ursi (Bearberry). A creeping, vinelike shrub with small leaves, abundant in Canada, forming broad mats over rocky ledges and slopes. Berries red.

Bryanthus (See *Phyllodoce*.)

Calluna vulgaris (Scotch Heather). Flowers pink, July and August. There is a white variety. (See page 848.)

Chimaphila umbellata (Prince's Pine, or Pipsissewa).

Cotoneaster adpressa and *C. microphylla*. Resemble *C. horizontalis*, mentioned above, but are more dwarf and evergreen. Both have a neat habit and glossy foliage. May not be hardy everywhere, but should be tried for low, stiff edging. (See under *A New Nursery List*, page 859.)

Daphne cneorum (Garland Flower). Dense and compact. Pink flowers in May. Excellent for edging. From 6 to 12 inches high. Twigs flexible and leathery, as those of *D. mezereum*, described above under *Deciduous*.
Dendrium [= *Leiophyllum*] *buxifolium* (Sand Myrtle). A dense shrub, to 3 feet high. There is a low, tufted form, var. *prostratum*. Flowers white or blush in May.
Empetrum nigrum (Black Crowberry).
Erica carnea (Hardy Spring Heath). Pink in April and May. From 6 to 12 inches high.
Gaultheria procumbens (Wintergreen, or Checkerberry.)
Gaylussacia brachycera (Box Huckleberry). Very dwarf and compact.
Juniperus chinensis var. *procumbens*. An excellent low Juniper. (Page 859.)
Juniperus sabina var. *tamariscifolia*. A very neat Juniper for edging. (Page 859.)
Leiophyllum. (See *Dendrium*.)
Lycopodium obscurum (Ground Pine). A native Club Moss related to Trailing Christmas Green (*L. complanatum*), but with stems erect and treelike, to 12 inches high.
Lysimachia nummularia (Moneywort, or Creeping Charlie). (See note under following plant.)
Mitchella repens (Partridge Berry). This and the preceding are two creeping, vine-like plants excellent for the rock garden. Moneywort has bright yellow flowers in June, and Partridge Berry has handsome red berries all winter.
Pachysandra terminalis. (See under *Low Woody Plants for Ground Cover*, page 853.)
Phyllodoce [= *Bryanthus*] *cærulea* (Mountain Heath). A low alpine shrub, from 3 to 6 inches high. Flowers pinkish purple, July.
Potentilla tridentata. Plant from 4 to 8 inches high, forming thick mats. Foliage bronzing in winter. Flowers white, strawberry-like.
Rhododendron [= *Azalea*] *hinodegira*. A low shrub, better than *R. amœna;* leaves larger, and flowers a brilliant red. Late May and early June.

WOODY PLANTS ENDURING SHADE

For Dry Soil

Any of the plants in this dry-soil list will grow better in sunlight than in shade, and will also grow better and more vigorously if the soil is moist.

Vines

Myrtle, or Periwinkle (*Vinca minor*). An evergreen trailing vine, excellent for ground cover in the shade but also good in sunlight.
Climbing Bittersweet (*Celastrus scandens*). A vigorous twining vine, native and deciduous. Has attractive orange berries all winter.

Shrubs

Small (From 1 to 4 feet)
Early Low Blueberry (*Vaccinium pennsylvanicum*). Grows from 6 to 12 inches high.
Mountain Currant (*Ribes alpinum*). Grows from 2 to 3 feet high.
Coralberry (*Symphoricarpos vulgaris*). Grows from 3 to 4 feet high, or higher.

Medium (From 6 to 8 feet)
Common Barberry (*Berberis vulgaris*).

Large (From 10 to 15 feet)
Witch-hazel (*Hamamelis virginiana*).
Privet (*Ligustrum vulgare* and *L. ibota*).
Buckthorn (*Rhamnus cathartica*).

Trees

Tree of Heaven (*Ailanthus glandulosa*).
Honey Locust (*Gleditsia triacanthos*).

For Moist Soil

All the dry-soil plants in the preceding list will grow better in moist soil and should be considered with the plants in this list.

Vines

Deciduous
Moonseed Vine (*Menispermum canadense*).
Common Greenbrier (*Smilax rotundifolia*).

Evergreen

English Ivy (*Hedera helix*). Is somewhat tender north of New York City.

Evonymus radicans var. *vegeta*. Hardier than the preceding. (See *Vines for Brick and Stone*, page 849.)

Moneywort (*Lysimachia nummularia*). (See page 856.)

Pachysandra terminalis. (See page 853.)

Shrubs

Deciduous

Small (From 2 to 4 feet)

Black Huckleberry (*Gaylussacia resinosa* [= *G. baccata*]). Grows from 18 inches to 2 feet high.

Maple-leaved Viburnum (*Viburnum acerifolium*). Grows from 4 to 6 feet high.

Yellowroot (*Xanthorhiza apiifolia*). Grows from 18 inches to 2 feet high.

Medium (From 6 to 8 feet)

High Bush Blueberry (*Vaccinium corymbosum*).

Azaleas, in order of bloom from May 1 to July 1. (See note on page 837.)

NOTE.—Azaleas will not thrive unless they are provided with plenty of good wood soil.

Large (From 10 to 15 feet, or higher)

Spicebush (*Benzoin æstivale* [= *B. odoriferum*]).

Speckled Alder (*Alnus incana*). (See also under *Trees*, below.)

Mountain Maple (*Acer spicatum*).

Redbud, or Judas Tree (*Cercis canadensis*). (See also under *Trees*, below.)

Evergreen

Small (From 1 to 3 feet)

Ground Hemlock, or Native Yew (*Taxus canadensis*).

Oregon Grape (*Mahonia aquifolium*). A blue-fruited barberry, with glossy, compound, evergreen leaves.

Large (From 6 to 10 feet, or higher)

Mountain Laurel (*Kalmia latifolia*).

Hardy Rhododendrons. (See page 818.)

Trees

Small

Flowering Dogwood (*Cornus florida*).

Striped, or Goosefoot, Maple, or Moosewood (*Acer pennsylvanicum*).

Shadbush, or Juneberry (*Amelanchier canadensis* and *A. lævis*).

Speckled Alder (*Alnus incana*).

Hornbeams, both Carpinus and Ostrya.

Redbud, or Judas Tree (*Cercis canadensis*).

Large

Beech (*Fagus ferruginea*).

Hemlock (*Tsuga canadensis*). Evergreen.

WOODY PLANTS ENDURING DRY SOIL IN SUNLIGHT

All the dry-soil plants in the preceding shade list will grow better in full sunlight and should be considered with the plants in this list.

Vines

Japanese Honeysuckle (*Lonicera japonica*). Excellent for covering a bank. Hall's Honeysuckle is a fall-blooming variety. (See under *Vines for Foliage*, page 850.)

Virginia Creeper, Woodbine, or Five-leaved Ivy (*Ampelopsis quinquefolia*, now called *Parthenocissus quinquefolia*). The first vine to color in the fall.

Shrubs

Deciduous

Small (From 2 to 4 feet)

New Jersey Tea (*Ceanothus americanus*).

Sweet Fern (*Myrica asplenifolia*).

Shrubby St.-John's-wort (*Hypericum prolificum*).

Fragrant Sumac (*Rhus canadensis* [= *R. aromatica*]).

Dwarf Willow (*Salix tristis*).

Medium (From 6 to 8 feet)
Panicled Dogwood (*Cornus paniculata*). Often 7 or 8 feet high.
Bayberry (*Myrica carolinensis*). (See also *M. cerifera* in index.)
Prairie Willow (*Salix humilis*).

Large (From 10 to 15 feet)
Bear, or Scrub, Oak (*Quercus nana* [= *Q. ilicifolia*].
Staghorn Sumac (*Rhus typhina* [= *R. hirta*]). Often from 15 to 20 feet high.

Evergreen (See also *Evergreen Shrubs*, page 817.)
Juniperus sabina. From 4 to 6 feet high. Branches spreading. Foliage a good green all winter.
Juniperus sabina var. *prostrata*. From 6 inches to 3 feet high. Low and prostrate, with ascending branches. Foliage steel blue in Waukegan's variety (page 853).
Common Juniper, low form (*Juniperus communis* var. *montana*). The two preceding species are better than this form of Common Juniper, which is about 1 foot high, with foliage usually browning in winter.

Trees

Deciduous
Tree of Heaven (*Ailanthus glandulosa*).
Hackberry (*Celtis occidentalis*).
Common Locust (*Robinia pseudacacia*).
Honey Locust (*Gleditsia triacanthos*).
Scarlet and Red Oak (*Quercus coccinea* and *C. rubra*). These will endure poor, dry soil better than any other Oaks.

Evergreen
Red Cedar (*Juniperus virginiana*).
Pitch Pine (*Pinus rigida*).
Banks' Pine (*Pinus banksiana* [= *P. divaricata*]).

NOTE.—The White Pine and the Hemlock are the noblest of the northern evergreens. The White Pine does fairly well in dry soil, although not so well as the Pines mentioned above. The Hemlock needs cooler and more moist conditions, and therefore is better suited for shade.

WOODY PLANTS ENDURING WET SOIL

(Arrangement is alphabetical by scientific names. See also *Hardy Aquatic Plants*, page 878)

Vines

Virgin's Bower (*Clematis virginiana*).
Moneywort, or Creeping Charlie (*Lysimachia nummularia*). This is low and creeping, and is commonly evergreen like Partridge Berry (*Mitchella repens*) which it much resembles. (See under *Low Woody Plants for Rock Garden or Small Edging*, page 854, and *Rock Garden Perennials*, page 871.)
Moonseed Vine (*Menispermum canadense*).
Swamp Dewberry (*Rubus hispidus*)
Common Greenbrier (*Smilax rotundifolia*).
Trumpet Creeper (*Tecoma* [= *Bignonia*] *radicans*).

Shrubs

Small (From 2 to 4 feet)
Red and Black Chokeberries (*Aronia* [= *Pyrus*] *arbutifolia* and *A. nigra*). These will grow from 6 to 8 feet high, but should be kept low. (See under *Deciduous Shrubs for Foliage*, page 825.)
Inkberry (*Ilex glabra*). A very graceful evergreen, sometimes reaching 8 feet.
Sweet Gale (*Myrica gale*).
Wild Black Currant (*Ribes floridum*).
Swamp Gooseberry (*Ribes lacustre*).
Flowering Raspberry, or Thimbleberry (*Rubus odoratus*).
Meadowsweet, or Queen of the Meadow (*Spiræa salicifolia* [= *S. alba*]). Grows from 3 to 5 feet high.
Steeplebush, or Hardhack (*Spiræa tomentosa*).

Medium (From 6 to 8 feet)

Buttonbush (*Cephalanthus occidentalis*).
Sweet Pepperbush (*Clethra alnifolia*).
Silky, or Purple-stemmed, Dogwood (*Cornus amomum* [= *C. sericea*]).
Red Osier Dogwood, or Red-stemmed Dogwood (*Cornus stolonifera*).
Winterberry (*Ilex verticillata*).
Mountain Laurel (*Kalmia latifolia*). The best broad-leaved evergreen shrub, sometimes growing from 10 to 12 feet high, or higher. (See page 818.)
Blue Honeysuckle (*Lonicera cærulea*).
Swamp Azalea (*Rhododendron* [= *Azalea*] *viscosum*). (See list of Azaleas under note at end of *April*, page 837.)
Swamp Rose (*Rosa carolina*).
Silky Willow (*Salix sericea*).
Red Elderberry (*Sambucus racemosa*).
Withe-rod (*Viburnum cassinoides*).

Large (From 10 to 15 feet)

Speckled Alder (*Alnus incana*).
Spicebush (*Benzoin æstivale* [= *B. odoriferum*]).
Willows (*Salix cordata*, *S. discolor*, and others).
Black Elderberry (*Sambucus canadensis*).
Arrowwood (*Viburnum dentatum*).
Nannyberry, or Sheepberry (*Viburnum lentago*).

Trees

Red Maple (*Acer rubrum*).
River, or Red, Birch (*Betula nigra*).
Tamarack, or American Larch (*Larix americana*).
Sour Gum, or Tupelo (*Nyssa sylvatica*).
Sycamore (*Platanus occidentalis*).
Poplars (*Populus deltoides*, *P. tremuloides*, and others).
Pin Oak (*Quercus palustris*).
Swamp White Oak (*Quercus platanoides*).
Willows (*Salix alba* var. *vitellina* and *S. nigra*).
American Elm (*Ulmus americana*).

A NEW NURSERY LIST

(Woody plants, old and new, which are not commonly found in nurseries but which should be propagated and widely used. Arrangement is alphabetical by scientific names)

Deciduous

Acer saccharum var. *monumentale*. A substitute for Lombardy Poplar.
Æsculus carnea var. *briotii*. The best red Buckeye.
Æsculus parviflora [= *Pavia macrostachya*].
Aronia [= *Pyrus*] *arbutifolia*.
Azaleas. (See *Rhododendrons*.)
Betula nigra.
Buddleia variabilis [= *B. davidii*] var. *magnifica*.
Cornus florida var. *rubra*.
Cotoneaster franchettii. Similar to, but better than, *C. simonsii*.
Cotoneaster horizontalis. Low and spreading, in dense mats from 2 to 3 feet high, or growing taller if trained against a wall. Leaves small, dark green, semi-evergreen. (See *Evergreen* list for *C. adpressa* and *C. microphylla*, which are practically evergreen.)
Cratægus cordata [= *C. phænopyrum*].
Evonymus obovata.
Hamamelis japonica var. *arborea*.
Hydrangea quercifolia. A low shrub native in the South, with fine, strong foliage.
Hypericum prolificum.
Ilex decidua. Has dark, glossy foliage.
Ligustrum vulgare.

Lonicera bella.
Lonicera fragrantissima.
Lonicera heckrottii.
Lonicera maackii. A vigorous, upright shrub, growing to a height of 10 feet, with handsome dark green leaves abruptly drawn into a long point. Flowers and fruits appear much later than on other Bush Honeysuckles.
Lonicera morrowii. A broad, spreading shrub, 7 feet high.
Magnolia conspicua [= *M. yulan*].
Magnolia glauca.
Magnolia stellata.
Myrica carolinensis. (See also *M. cerifera* in index.)
Nyssa sylvatica.
Oxydendrum arboreum.
Philadelphus lemoinei.
Platanus orientalis. An excellent street tree.
Prunus sargentii.
Quercus nana [= *Q. ilicifolia*] (Bear, or Scrub, Oak). A shrubby Oak growing naturally in thickets on dry rocky soil. Leaves small, holly-like, green above and white hairy below
Rhododendrons. (See note on Azaleas under *April*, page 837.)
Rhus canadensis [= *R. aromatica*].
Rosa lucida. The best of our native Roses. Pink or white in variety.
Rosa multiflora var. *cathayensis.* A Chinese rose, hardy and vigorous, with habit like that of *R. multiflora* but bearing clusters of large, pinkish flowers with handsome yellow stamens. The original wild type giving rise to Seven Sisters and Crimson Rambler.
Rosa setigera (Prairie Rose). A vigorous native pink climbing Rose, 6 feet high, with recurving and trailing stems.
Rosa spinosissima var. *altaica.* The Siberian form of the Scotch Rose. White, with conspicuous yellow stamens.
Salix babylonica var. *ramulis aureis.* A hardy, yellow-twigged Weeping Willow.
Salix pentandra [= *S. laurifolia*] (Laurel-leaved Willow).
Salix tristis.
Smilax glauca.
Smilax rotundifolia.
Spiræa arguta. A substitute for the tenderer *S. thunbergii.*
Spiræa bracteata.
Syringa chinensis [= *S. rothomagensis*] (Rouen Lilac).
Tilia petiolaris (Weeping Silver Linden).
Vaccinium corymbosum (High Bush Blueberry).
Vaccinium pennsylvanicum (Early Low Blueberry). 1 foot high.
Viburnum acerifolium.
Viburnum carlesii. A new plant from Korea.
Viburnum prunifolium.
Vitis coignetiæ (Crimson Glory Vine).

Evergreen

Abies brachyphylla [= *A. homolepis*]. From Japan.
Arctostaphylos uva-ursi (Bearberry).
Arundinaria japonica.
Baccharis halimifolia.
Berberis sargentiana. A shrub from western China, growing to 3 feet high. The handsomest evergreen Barberry. Leaves simple, not compound as those of Mahonia, thick and firm, dark green above, lighter below.
Berberis verruculosa. From western China. Dwarf shrublike above, leaves strongly spiny-toothed, dark glossy green above and white below.
Buxus japonica.
Calluna vulgaris (Scotch Heather).
Chamæcyparis nootkatensis [= *C. nutchaensis*] (Yellow Cedar, or Nootka Cypress of the West). Has handsome foliage, and is hardy but as yet little cultivated in the East.
Chamæcyparis obtusa.

Chamæcyparis pisifera. This and the preceding are Japanese Cypresses, often called Retinosporas. They are both handsomer than the three common *pisifera* varieties known commercially as *Retinospora plumosa*, *R. filifera*, and *R. squarrosa*

Cotoneaster adpressa and *C. microphylla.* Both of these are dwarf and dense, growing only a few inches high, and are excellent for edging or rock garden. *C. adpressa* has the larger leaves, which are crimped, or wavy. (See *Deciduous* list for *C. horizontalis*, which is only semi-evergreen.)

Daphne cneorum.

Dendrium [= *Leiophyllum*] *buxifolium* (Sand Myrtle).

Erica carnea. A hardy spring-blooming Heath.

Evonymus radicans var. *vegeta.* A broad, round-leaved variety, and a hardier substitute for English Ivy.

Gaylussacia brachycera (Box Huckleberry).

Hypericum calycinum (Aaron's Beard). Leaves oblong, from 1 to 2 inches long, dark green above, blue-gray below. Plant low, 1 foot high or less, spreading in dense masses. Good for ground cover, but may be tender in the northern parts of the State.

Ilex crenata var. *microphylla.* An excellent, tall, hedge plant. This small-leaved form has passed through the severe winters of the last five years in the Arnold Arboretum at Boston without injury.

Ilex glabra.

Juniperus chinensis. This resembles the native Red Cedar, but is better because the foliage does not brown in winter. Also the leaves are more spreading and their bluish gray upper surfaces are more noticeable, which gives the spray a fuller and lighter-colored appearance.

Juniperus chinensis var. *pfitzeriana.* A shrub, with wide, up-flaring branches to 10 feet; branches nodding, making a large, loose, handsome spray. A new and very striking type, but liable to injury from splitting of the branches.

Juniperus chinensis var. *procumbens.* Plant low and prostrate, rarely 2 feet high. Spray dense, compact, remaining green all winter. An excellent low Juniper.

Juniperus sabina. A handsome, spreading shrub, with ascending branches from 4 to 10 feet. Foliage dark green all winter.

Juniperus sabina var. *prostrata* [= *J. horizontalis*]. Plant lower than the preceding, usually with long, trailing branches and numerous short ascending branchlets, sometimes shrubby to 4 feet with spreading branches. Foliage steel blue, turning grayish purple in winter. Waukegan's Juniper (*J. horizontalis* var. *douglasii*) is a distinctly low, trailing form of *J. sabina* var. *prostrata.*

Juniperus sabina var. *tamariscifolia.* This has foliage somewhat like that of *J. chinensis* var. *pfitzeriana*, described above, but is not so loose and spreading. The plant is lower and more compact, from 2 to 3 feet high, with short horizontal branches and upcurving branchlets, making a neater and finer effect. An excellent variety.

Juniperus virginiana var. *glauca.* This is the best blue-gray tree juniper type.

Leucothoë catesbæi.

Mahonia repens.

Pachysandra terminalis.

Picea omorika. A new plant from the Balkans.

Pinus banksiana [= P. *divaricata*].

Pinus cembră.

Pinus densiflora, and var. *pumila* (Japanese Red Pine)

Pinus ponderosa (Western Yellow Pine).

Pinus resinosa.

Pinus thunbergii (Japanese Black Pine).

Pseudotsuga taxifolia [= *P. douglasii*]. Only the Rocky Mountain form of this should be bought.

Rhododendron arbutifolium [= *R. wilsonii*].

Rhododendron carolinianum [= *R. punctatum* in part]. (See index.)

Rhododendron [=*Azalea*] *hinodegira.* Small, with bright red flowers.

Rhododendron myrtifolium.

NOTE.—These four Rhododendrons are excellent low forms, with small foliage, good for borders or low plantings.

Rubus spectabilis var. *plena*. A handsome semi-evergreen blackberry, erect to from 12 to 18 inches, with curving and long trailing stems. Leaflets large, about 1½ inches long or longer, and white woolly below.

NOTE.—This is included by some botanists under *Rubus fruticosus*, but it should be called *Rubus linkianus* Seringe, which is a cultivated form, with double or semi-double flowers, common in northern and middle Europe and escaped in New England.

Taxus baccata var. *repandens*. The hardiest form of English Yew, low and recurving, from 1½ to 2 feet high.

Taxus cuspidata (Japanese Yew). The best of the Yews.

Thuya gigantea (Giant Arbor Vitæ, or Red Cedar of the West). The best of all Arbor Vitæs. Foliage very flat, and composed of slender, very regularly arranged, feather-like branchlets, dark glossy green above, whitish below. Plant hardy, but as yet little cultivated in the East. Only Rocky Mountain seed, not that of the Coastal Plain, should be bought.

Thuya japonica. A tree similar to the preceding, but smaller, the spray not so flat, and the branchlets thicker and irregularly arranged.

Tsuga canadensis.

Tsuga caroliniana. Smaller, but even more graceful, than the preceding, with larger and more spreading leaves, making a looser, more feathery spray.

Viburnum rhytidophyllum. A large, rare, evergreen Viburnum, with striking foliage. Plant probably hardy, although the foliage was scorched a little at Highland Park, Rochester, during the severe winter of 1913–1914. Leaves narrow oblong, from 3 to 7 inches long, deeply wrinkled and dark lustrous green above, densely yellowish below. Berries red.

THE LAWN

Preparation of the Lawn

The following directions are offered for the proper preparation of the lawn:

1. Underdrain on heavy soils and wherever the soil is low and wet.

2. Do not strip the topsoil unless this is necessary in order to make changes in grade or to provide for excavations, or for other purposes, in which case the topsoil should be piled at one side and later returned after the subsoil has been properly graded, manured, and plowed according to directions given in the paragraph following. The existing relation between surface and subsoil should be disturbed as little as possible.

3. Make a heavy application (30 tons per acre) of stable manure, well rotted if possible, in August, before the fall rains begin, and plow under deeply, subsoiling if the soil is stiff and hard below. If it is necessary to seed to permanent lawn at once, only 15 tons of manure should be used and it should be well rotted. This is because no second cross-plowing in spring, as advised in paragraph 6, will be possible. Such a heavy application of manure as 30 tons per acre would not become well incorporated with the soil by one plowing, and would be likely to make the soil too dry and loose to insure a good lawn if the seeding were done at once. At this point attention should be given to the matter of trenches or any deep fills in the lawn. If permanent seeding is to be done at once, the grade over such places should be left high to allow for settling.

4. Apply lime at the rate of at least one and one-half tons per acre of hydrated lime or three tons per acre of ground limestone which has passed through a screen of 20 meshes to the inch or, better, 50 meshes. The limestone is slower to act than the hydrated lime, and a greater quantity is required; but it is usually cheaper, and is much more convenient to handle. For correcting a soil deficient in lime, 2000 pounds of ground limestone is equivalent to 1480 pounds of hydrated lime or 1120 pounds of quicklime or stone lime, assuming that all the materials are chemically pure. Under ordinary commercial conditions of impurity the equivalent would be 2000 pounds of ground limestone, 1400 pounds of hydrated lime, or 1500 pounds of stone lime. After the lime is broadcasted and harrowed in, seed down to rye (1½ bushels per acre) and hairy vetch (20 pounds per acre) for winter cover crop.

5. Liming not only corrects a soil deficient in lime, but also loosens a heavy clay soil, thus improving its physical condition. Liming is good treatment for almost any soil,

but is especially good for lawn soils because blue grass, the standard grass in all lawn mixtures, needs lime in the soil. Redtop and Rhode Island bent will grow on soil deficient in lime, but blue grass will not.

6. Turn under the rye and the vetch in spring by cross-plowing, about May 5 to 15 or as soon as the soil is dry enough to work. Broadcast and harrow in thoroughly, at the rate of 800 pounds per acre, a 3:9:4 commercial fertilizer — that is, one analyzing 3 per cent nitrogen, 9 per cent phosphorus, and 4 per cent potash. To prepare such a fertilizer, use the following formula: 200 pounds of cottonseed meal, 100 pounds of bone meal (or 500 pounds of raw rock phosphate), 100 pounds of nitrate of soda, 50 pounds of kainit, 50 pounds of muriate of potash, and 300 pounds of acid phosphate. (It will be noted that both quick-acting and slow-acting chemicals are combined in this fertilizer.) Seed down to a cover crop for green manure, such as Canada peas, using two bushels to an acre.

7. Plow under the cover crop early in July while it is still in bloom, and cultivate lightly for six weeks in order to kill weeds and to preserve the surface mulch. This also gives time for the soil to settle after the cover crop is turned under.

8. Late in August rake the lawn thoroughly in order to establish a perfect seed bed and surface grade. If the seed is broadcasted by hand and not spread by a lawn seeder, the lawn should be seeded both ways so as to insure a uniform seeding. Rake in the seed lightly, and roll. Top-dress with about one-half inch of sheep manure or old well-rotted stable manure which has been well forked and put through a fine screen. This will keep the soil from becoming dry and hard on top, and will greatly facilitate watering when this is necessary to start germination in dry weather. Late summer seeding is usually better than spring seeding because weeds do not start as readily at this time as do lawn grasses, which get a good start and become well established by spring.

9. For a general seed mixture, combine three parts of blue grass, one part of redtop, and one part of Rhode Island bent, or omit the redtop and substitute two parts of Rhode Island bent. Use only the best grades. From 75 to 100 pounds an acre (from 5 to 6 bushels) is a heavy seeding, but is not too much. This is at the rate of one quart to one square rod, or about 300 square feet. In such a mixture the redtop and the Rhode Island bent will show in the lawn first, and later the blue grass will gradually take possession. In spring white clover may be added, from four to eight quarts to an acre. In most cases the use of a little white clover on the lawn is merely a matter of preference; but on grass walks, tennis courts, bowling greens, golf links, and the like, white clover is entirely too soft to stand the wear.

10. Roll lightly with a hand roller after the seed is well started. This firms the soil about the grass roots and is supposed to make the grass stool (spread out) more. Usually fall seeding does not need watering, but if necessary soak the lawn thoroughly, using a spray light enough not to wash out the seed. Do the work late in the day and do it slowly and thoroughly, sprinkling each part over and over again until the soil is wet to a depth of from 8 to 10 inches. One such good soaking is worth a dozen sprinklings. (Old lawns that are sloping are best watered by punching holes in the sod with an iron bar and letting the water run in slowly until the soil is soaked.)

11. Cut the grass as soon as it is high enough, and continue to cut at frequent intervals, with the blade of the lawn mower set high. Leave the clippings on the lawn. Mulch lightly over winter with well-rotted manure, and early in spring firm the soil with a roller before regular cutting begins.

12. For top-dressing in spring or fall, just as growth is beginning, use not more than 200 pounds each of nitrate of soda and acid phosphate, and 50 pounds of kainit, to an acre. This is at the rate of one pound of each to one square rod or about 300 square feet. In sandy or light soil, use only one-half this amount and put it on in two applications instead of in one. Break up all lumps, mix with equal parts of sand or fine loam, and broadcast evenly. Spread just before a shower, or wash in with the hose. Do not allow the fertilizer to stand mixed, for the nitrate will collect moisture and harden the whole mixture. Sheep manure is excellent for top-dressing, but at present it is more expensive than the chemicals and it is liable to adulteration.

Grasses for Different Purposes

Standard Varieties

Blue Grass (*Poa pratensis*). Grows slowly, but comprises the bulk of every mixture except on soils deficient in lime, as along the Atlantic coast.

Redtop (*Agrostis alba* [= *A. vulgaris*]). Grows rapidly and is good on soil deficient in lime. In ordinary soils, when Blue Grass and Redtop are used together the Redtop will show in the lawn first and later the Blue Grass will gradually take possession.

Low and Creeping (For putting greens and other sandy soils)
Rhode Island Bent (*Agrostis alba* var. *vulgaris* [= var. *canina*]).
Creeping Bent (*Agrostis alba* var. *maritima* [= var. *stolonifera*]).

For Holding Shifting Sand
Beach Grass (*Ammophila arenaria*).

Quick-growing Grass
For level areas
Italian Rye (*Lolium multiflorum* [= *L. italicum*]). This is often used in general mixtures, to give a quick showing of green. In the North it usually dies out after the first winter, and for this reason is better than English, or Perennial, Rye (*Lolium perenne*), which often lasts for three or four years in this country.

For banks
White Clover (*Trifolium repens*). This is too soft for heavy wear. (See page 861.) It thrives best in heavy soil.
Creeping Bent (*Agrostis alba* var. *maritima* [= var. *stolonifera*]). Good in gravelly soil.
Crested Dog's-tail (*Cynosurus cristatus*). Good in shade.

For Light and Dry Soil
Creeping Bent (*Agrostis alba* var. *maritima* [= var. *stolonifera*]).
Red Fescue (*Festuca rubra*). This is better and more stoloniferous than the species following.
Sheep Fescue (*Festuca ovina*).

For Shady Places
Various-leaved Fescue (*Festuca heterophylla*).
Wood Meadow Grass (*Poa nemoralis*).
Crested Dog's-tail (*Cynosurus cristatus*).

NOTE.—In very shady places where a permanent turf is hard to establish, an annual sowing of Italian Rye has proved satisfactory. Under lawn conditions, when the grass is kept mowed, the Italian Rye will last over the first winter.

Enemies to Lawns

Weeds.— Many patent remedies have been tried against weeds, but the only satisfactory procedure is to dig them out, fill the holes with good soil, and reseed.

Angleworms.— For destruction of angleworms a stock solution is prepared in the following manner: One pound of salt is dissolved in two gallons of boiling water, one pound of corrosive sublimate is added, and the whole is diluted with four gallons of water. One pint of this stock solution in sixteen gallons of water is sprayed over the lawn.

Army Worms.—While the army worms are still small and are feeding actively, the lawn should be sprayed until it is white with arsenate of lead, three pounds to fifty gallons of water.

White Grubs.— On large areas much infested with white grubs, the lawn should be rolled with a ten-ton roller when it is dry and before the beetles emerge in August. At this time (late July and early August) the grubs are among the grass roots near the surface, preparing to pupate and to emerge as adult beetles, and they will be crushed by the roller.

BULBS, ANNUALS, AND HERBACEOUS PERENNIALS

(Further information on the plants in this section may be obtained from the Department of Floriculture, Cornell University)

In the following tables, the blooming periods are inclusive; that is, July-September means blooming continuously through July, August, and September.

Bulbs

Classification into two groups is made for convenience. The prevailing color of the blooms, the season of flowering, and the height, are given for each variety. Group I includes species most suitable for formal beds. Group II includes species for natural plantings. The varieties marked with an asterisk are especially desirable, and those marked with two asterisks are also good for naturalization in the grass.

	Color	Season	Height
Group I			
Hyacinthus orientalis (Dutch Hyacinth). Gertrude, bright pink; La Grandesse, pure white; L'Innocence, pure white; Czar Peter, porcelain blue; Grand Maître, sky blue; King of Blues, dark blue; Grandeur à Merveille, blush white; City of Haarlem, deep yellow; Robert Steiger, deep crimson.	Various........	April–May..	12 inches
**Narcissus incomparabilis*.............. Sir Walter Scott, Queen Bess, Princess Mary, Sir Watkin.	Yellow.........	April–May..	15 inches
**Narcissus leedsii*..................... Dutchess of Westminster variety.	Yellow	April–May..	15 inches
**Narcissus pseudo-narcissus* (Common Daffodil). Emperor, Empress, Golden Spur, Horsfieldii, and Trumpet (maximus), are among the best of the varieties.	Yellow.........	April–May..	15 inches
*Tulips:			
Early varieties: Cottage Maid, rose pink and white; Flamingo, bright rosy red; Keizer Kroon, red and yellow; Pottebakker, white, yellow, and scarlet varieties; Proserpine, carmine-rose; White Swan, pure white.	Various........	Late April–late May	12 inches
Late varieties: Darwin, Gesneriana, Parrot Picotee.	Various........	Middle May–early June	12 to 15 inches
Group II			
Chionodoxa luciliæ (Glory of the Snow).	Blue, with white center	March–April	6 inches
**Colchicum autumnale* (Autumn-flowering Crocus).	Various........	August–September	6 inches
**Crocus...........................	White, lilac, purple, yellow, and mixed	March–April	6 inches
***Eranthis hyemalis* (Winter Aconite)....	Yellow.........	March–April	6 inches
Fritillaria:			
F. imperialis (Crown Imperial)......	Red...........	May.......	3 to 4 feet
***F. meleagris* (Guinea-hen Flower)....	Yellow, variously checkered with green, white, and purple	March–April	12 inches
***F. meleagris* var. *alba*...............	White..........	March–April	12 inches

Bulbs (*concluded*)

	Color	Season	Height
Group II (*continued*)			
***Galanthus nivalis* (Snowdrop)	White	March–April	6 inches
**Lilium (Lilies). (See *Narrow Upright Perennials*, page 869.)			
Muscari (Grape and Feathered Hyacinths):			
***M. botryoides*	Blue	April–May	6 inches
***M. botryoides* var. *alba*	White	April–May	6 inches
M. plumosum var. *monstrosum*	Mauve	April–May	12 inches
***Narcissus poeticus* (Poet's Narcissus)	White, with deeply colored eye	April–May	12 inches
Scilla (Squills):			
***S. campanulata* [= *S. hispanica*]	Blue	May–June	12 inches
***S. campanulata* var. *alba*	White	May–June	12 inches
S. campanulata var. *carnea*	Rose	May–June	12 inches
***S. nutans* (Bluebells)	Blue	May–June	12 inches
***S. sibirica*	Blue	May–June	4 to 6 inches
S. sibirica var. *alba*	White	May–June	4 to 6 inches

Annuals

Annuals that are best adapted to make a continuous display are given in the list below. Species marked with an asterisk are recommended for cut flowers. The following classification is made relative to hardiness: Class A, hardy annuals; Class B, half-hardy annuals; Class C, tender annuals.

	Color	Height
Class A. Hardy Annuals (To be sown in May or earlier)		
Ageratum (Floss Flower)	Blue	9 inches
**Alyssum maritimum*	White	9 inches
*Antirrhinum (Snapdragon)	Various	9 to 24 inches
Cacalia aurea [= *Emilia flammea*] (Tassel Flower)	Deep orange	1 foot
**Centaurea cyanus* (Bachelor's Button)	Various	2 to 3 feet
Clarkia pulchella	Bright carmine	18 inches
Convolvulus minor	Blue	1 foot
**Coreopsis* [= *Calliopsis*] *coronata*	Orange	1 foot
**Coreopsis* [= *Calliopsis*] *drummondii*	Yellow and red	2 feet
Delphinium (Larkspur)	Various	18 inches
*Dianthus (Pink)	Various	1 foot
Eschscholtzia californica (California Poppy).	Yellow	9 inches
Gaillardia (Blanket Flower)	Various	18 inches
Gilia tricolor	Lilac, white, and purple	1 foot
**Gypsophila elegans* (Annual Baby's Breath)	White	18 inches
Helianthus annuus (Sunflower)	Yellow	4 to 6 feet

Annuals (*concluded*)

	Color	Height
Class A. Hardy Annuals (*continued*)		
Iberis umbellata (Candytuft)...........	White, purple, lavender..	1 foot
Ipomœa purpurea (Morning-glory)..... A climber, making a rapid growth.	Various................	10 feet
**Lathyrus odoratus* (Sweet Pea).........	Various................	5 feet
Linum coccineum [= *L. grandiflorum*] (Flowering Flax).	Scarlet.................	18 inches
Lupinus nanus.......................	Shaded blue and white...	1 foot
Mirabilis jalapa (Four-o'clock).........	Various................	18 inches
Nemophila insignis..................	Blue....................	9 inches
Nigella damascena (Love-in-a-mist).....	Blue and white..........	1 foot
Œnothera drummondii var. *nana* (Dwarf Evening Primrose).	Yellow.................	6 inches
Papaver rhœas (Shirley Poppy)........	Various................	18 inches to 2 feet
**Phlox drummondii*....................	Various................	6 to 9 inches
**Reseda odorata* (Mignonette)...........	Yellow and greenish white	9 inches
Rudbeckia bicolor var. *superba* (Black-eyed Susan).	Yellow and brown.......	2 feet
Schizanthus (Butterfly Flower).........	Various................	18 inches
Tagetes signata var. *pumila* (Dwarf Marigold).	Yellow.................	1 foot
* *Viola tricolor* (Common Pansy)........ This plant is really biennial (see *Herbaceous Perennials*, page 870), but is commonly treated as an annual and renewed every year. The seed is sown in August; the plants are transplanted twice in flats, and either wintered in a cold frame and set out in spring, or set at once in permanent position in the border and later in the fall covered lightly for over winter with hemlock boughs and a few leaves.	Various................	6 to 9 inches
Zinnia.............................	Various................	9 to 18 inches
Class B. Half-hardy Annuals (To be sown in late May or early June)		
Amaranthus caudatus................	Crimson................	2 to 3 feet
Amaranthus speciosus................	Crimson................	2 feet
**Callistephus hortensis* (China Aster).....	Various................	6 inches to 2 feet
*Matthiola (Stock)..................	Various................	1 foot
Petunia...........................	Various................	6 to 9 inches
*Tropæolum (Nasturtium), dwarf.......	Various................	10 inches
Tropæolum (Nasturtium), tall, climbing.	Various................	4 to 6 feet
Verbena...........................	Various................	6 inches
Class C. Tender Annuals (Seeds should be started indoors; plants should be set out in June)		
Balsam............................	Various................	2 feet
Cosmos............................	Various................	3 feet
Dahlias, single.....................	Various................	3 to 4 feet
Nicotiana..........................	Various................	3 to 4 feet

Herbaceous Perennials

(The varieties marked with an asterisk are especially desirable)

	Color	Season	Height
Massive Background Perennials			
**Aruncus sylvester*. (See *Spiræa aruncus*.)			
**Aster novæ-angliæ* (New England Aster).	Rosy purple....	August–September	4 to 6 feet
Bocconia cordata (Plume Poppy)..... Has large, handsome leaves, with gray bloom like those of Bloodroot.	White..........	July–August	5 to 8 feet
**Boltonia asteroides*.................	White to lavender	September–October	5 to 7 feet
Chrysanthemum uliginosum (Giant Daisy).	White..........	August–September	4 to 5 feet
Helenium autumnale var. *superbum*...	Yellow.........	August–September	4 to 6 feet
Helianthus giganteus (Giant Sunflower).	Yellow.........	September–October	6 to 10 feet
Helianthus mollis..................	Yellow.........	July–August	4 to 5 feet
Helianthus orgyalis (Narrow-leaved Sunflower).	Yellow.........	September–October	8 to 10 feet
**Hibiscus* [= *Althæa*] *moscheutos* (Marsh, or Rose, Mallow). Has large, hollyhock-like flowers, white to rose, with dark centers.	White to rosy pink	August-September	4 to 6 feet
Lythrum salicaria var. *roseum superbum* (Purple Loosestrife).	Rosy purple....	July–August	5 to 7 feet
**Polygonum sieboldii* [=*P. cuspidatum*] An excellent foliage plant; leaves broad, heart-shaped; flowers small and white, in abundant lateral clusters. NOTE.—Buyers should be sure to get *P. sieboldii* [= *P. cuspidatum*], not *P. sachalinense*, which is larger and very rank in growth, spreads rapidly, and is almost impossible to eradicate.	White..........	August–September	5 to 6 feet
Rudbeckia laciniata var. *flore pleno* (Golden Glow). Is planted too extensively. Growth rank. Flowers a crude yellow.	Yellow.........	July–August	6 to 8 feet
Rudbeckia subtomentosa (Sweet Coneflower).	Yellow, with brown center	August–September	4 to 5 feet
Silphium laciniatum................	Yellow.........	July–September	5 to 6 feet
Solidago altissima (Goldenrod) Flowers in panicles.	Yellow	September–October	7 to 9 feet
**Spiræa aruncus* [= *Aruncus sylvester*] (Goatsbeard).	White..........	June–July..	4 to 6 feet
Good Foliage Perennials (Maintaining good foliage for the entire season, and safe as "filler" for making up the bulk of the planting; also excellent in flower)			

Herbaceous Perennials (*continued*)

	Color	Season	Height
Good Foliage Perennials (*continued*)			
**Anemone japonica* (Japanese Windflower).	White, red, and rosy pink	September–October	2 to 4 feet
**Aquilegia chrysantha* (Yellow Columbine).	Yellow.........	June-August	3 to 4 feet
**Aquilegia cærulea* (To be treated as a biennial).	Blue...........	May–June..	18 inches
**Aruncus sylvester*. (See *Spiræa aruncus*.)			
Astilbe japonica [= *Spiræa japonica*]..	White..........	June–July..	2 to 3 feet
*Chrysanthemums (Hardy Pompons).. The button, or small-flowering old-fashioned pompon, varieties. Flowers small and double, blooming until snow falls.	All colors except blue and purple	September–November	2 to 3 feet
Clematis recta.....................	White..........	June-July...	2 to 3 feet
Clematis stans.....................	Light blue......	September..	4 to 5 feet
**Dicentra spectabilis* (Bleeding Heart) Best in partial shade.	Rosy pink (red and white mixed)	May–June..	1½ to 2 feet
Dictamnus albus [= *D. fraxinella*] (Gas Plant). Foliage dark and glossy, with lemon odor when crushed.	White..........	June–July..	2 to 3 feet
*Ferns. (See under *Rock Garden Perennials*, page 871, *Perennials Enduring Shade*, page 875, and *Hardy Aquatic Plants*, page 880.)			
**Funkia subcordata* (Day Lily)...... Endures shade.	White..........	August–September	18 inches
Hemerocallis flava (Lemon Lily).... Endures partial shade.	Yellow.........	June–July..	2 to 3 feet
**Iris lævigata* [= *I. kæmpferi*] (Japanese Iris). Best when growing in water.	All colors except red	June–July..	2 to 3 feet
*Peonies...........................	All colors.......	May–June..	2 to 3 feet
**Phlox paniculata* [= *P. decussata*] (Late Phlox).	Many colors....	July–September	3 to 4 feet
**Phlox suffruticosa* (Early Phlox)	Several colors, from Miss Lingard, white, to Burns, rosy purple	June-August	2 to 3 feet
**Polygonum sieboldii* [= *P. cuspidatum*] var. *compactum*.	White..........	August–September	18 inches
**Spiræa aruncus* [= *Aruncus sylvester*] (Goatsbeard). An excellent plant anywhere. (See *Massive Background Perennials*, page 866.)	White..........	June–July..	4 to 6 feet
Spiræa japonica. (See *Astilbe japonica*.)			
Spiræa lobata [= *Ulmaria rubra* var. *venusta*] (Queen of the Prairie).	Deep pink......	June.......	3 to 4 feet
Spiræa palmata [= *Ulmaria purpurea*]	Carmine-pink...	July.......	3 to 4 feet

Herbaceous Perennials (*continued*)

	Color	Season	Height
Good Foliage Perennials (*continued*)			
**Statice latifolia* (Sea Lavender)...... Has large, handsome root leaves, surmounted by a cloud of tiny flowers in large, erect, spreading clusters.	Bluish purple...	August.....	1½ to 2 feet
**Stokesia cyanea* (Stokes' Blue Aster)..	Blue...........	July–September	18 inches
**Trollius europæus* (Globeflower).....	Bright yellow...	May–June..	12 to 18 inches
Ulmaria. (See *Spiræa*.)			
**Veronica longifolia* var. *subsessilis*...	Blue-purple.....	August–September	2 to 3 feet
NOTE.—Cannas are omitted from both the *Good Foliage* list and the *Bold Foliage* list (page 874), because the writer believes they are planted too extensively in the flower garden and the hardy border. For tropical and subtropical bedding they are indispensable, but in other places the large, tender leaves are very conspicuous, and the plant is not comparable to such good foliage types as Peonies, *Iris lævigata* [= *I. kæmpferi*], *Funkia subcordata*, Eulalia, *Hibiscus moscheutos*, or *Polygonum sieboldii*.			
Narrow Upright Perennials (Attractive when massed in groups with the good foliage types named above)			
**Aconitum autumnale* (Autumn Aconite, or Monkshood).	Deep blue......	July–September	4 to 5 feet
**Althæa rosea* (Hollyhock) in variety..	Various........	July–August	6 to 8 feet
**Campanula pyramidalis*, and var. *alba* (Chimney Plant, or Steeple Bells). To be treated as a biennial.	Blue and white..	July–August	4 to 6 feet
Delphinium elatum (Bee Larkspur)...	Blue...........	June-August	4 to 6 feet
Digitalis purpurea (Foxglove)....... Usually biennial	Pink-lavender...	June–July..	2 to 3 feet
**Digitalis purpurea* var. *alba* (Foxglove). Usually biennial. This white variety is much better than the type, listed just above.	White..........	June–July..	2 to 3 feet
*Gladiolus in variety...............	Various........	July–September	4 feet
Iris pallida var. *dalmatica*...........	Lavender.......	Last of May–June	2 to 4 feet
**Kniphofia* [=*Tritoma*] *pfitzeri* (Flameflower). Should be mulched over winter, or, better, stored in sand.	Orange-red.....	August–September	3 to 4 feet
Liatris pycnostachya (Blazing Star, or Gay Feather).	Rosy purple....	August–September	4 to 5 feet

Herbaceous Perennials (*continued*)

	Color	Season	Height
Narrow Upright Perennials (*continued*)			
******Lilium brownii***	White within, rosy violet without	July–August	4 feet
******Lilium candidum*** (Madonna Lily)	White	June–July	3 to 5 feet
******Lilium henryi***	Orange	August–September	4 to 5 feet
******Lilium speciosum* var. *album***	White	August–September	3 to 4 feet
******Lilium speciosum* var. *roseum***	Pink	August–September	3 to 4 feet
******Lilium speciosum* var. *rubrum***	Rosy pink, spotted red	August–September	3 to 4 feet
******Lilium tigrinum*** (Tiger Lily)	Orange, spotted purple	July–August	4 to 5 feet
Œnothera biennis var. *grandiflora* [=*Œ. lamarkiana*] (Lamark's Evening Primrose).	Yellow	June-August	4 to 5 feet
Pentstemon barbatus var. *torreyi*	Scarlet	July–August	4 to 5 feet
Solidago altissima (Goldenrod). Flowers in panicles.	Yellow	September–October	7 to 9 feet
Solidago lanceolata (Goldenrod). Flowers in flat-topped clusters.	Yellow	August–September	3 to 5 feet
Low Perennials for Edging or Ground Cover (See also *Low Woody Plants for Ground Cover*, page 852)			
Achillea tomentosa. Foliage feathery, downy, and evergreen.	Yellow	June–July	6 to 9 inches
Ægopodium podagraria var. *variegatum*. A very common foliage plant for edging. Leaves white-margined.	Creamy white	June	12 inches
Ajuga genevensis (Geneva Bugle). Foliage shining green.	Blue	May–June	8 inches
**Alyssum saxatile* (Golden Tuft). Foliage silvery.	Yellow	April–May	12 inches
Arabis albida (Rock Cress). Bloom profuse.	White	April–May	8 inches
**Armeria maritima* (Cushion Pink, or Thrift). Evergreen. Bloom profuse.	Pink	May–June	6 inches
**Aubrietia deltoidea* var. *græca* (Purple Rock Cress). An excellent low evergreen for edging.	Violet-purple	April–May	6 inches
**Campanula carpatica*	Deep blue	July–August	12 to 15 inches
**Campanula carpatica* var. *alba*	White	July–August	9 inches
Cerastium tomentosum. Foliage silvery.	White	June	3 to 6 inches
Ceratostigma plumbaginoides (Hardy Leadwort). Forms neat tufts.	Light blue	September–October	9 inches
**Convallaria majalis* (Lily of the Valley). Foliage a good green. Endures shade.	White	May–June	8 inches

Herbaceous Perennials (*continued*)

	Color	Season	Height
Low Perennials for Edging or Ground Cover (*continued*)			
Dianthus plumarius, Napoleon III variety (Napoleon III Pink). Foliage narrow. Bloom profuse.	Crimson........	June-August	12 inches
Houstonia cærulea (Bluets)......... Starry flowers on slender stems. Both this and *Phlox subulata* are wild plants which form great masses of bloom in the fields in May.	Pale blue.......	May.......	3 to 6 inches
**Iberis sempervirens* (Evergreen Candytuft). Foliage evergreen.	White..........	May–June..	12 inches
**Myosotis palustris* var. *semperflorens* (Ever-blooming Forget-me-not). Best with shade and moisture.	Blue...........	May-August	8 inches
* *Nepeta glechoma* [= *Glecoma hederacea*] (Ground Ivy, or Gill-over-the-ground). Best with shade and moisture. Good ground cover.	Blue...........	April-May..	4 inches
**Phlox subulata* (Moss Pink)........ Foliage evergreen, but weak and small, forming a mossy bed.	White, pink, or pale blue	April–May..	6 inches
Stellaria holostea (Easter Bell).......	White..........	May.......	12 inches
Veronica rupestris .... A dense trailing plant, forming thick mats.	Purple.........	May–June..	4 to 6 inches
* *Vinca minor* (Myrtle)............. A broad-leaved evergreen. Makes excellent ground cover in sunlight or shade.	Blue, with a white variety	May.......	6 inches
* *Viola cornuta* (Horned Violet, or Tufted Pansy). Foliage good.	White, yellow, or blue	May–October	8 inches
* *Viola tricolor* (Common Pansy)..... To be treated as an annual. (See note under *Hardy Annuals*, page 865.)	Many colors....	May–September	6 to 9 inches
Rock Garden Perennials (See also *Low Woody Plants for Rock Garden or Small Edging*, page 853.)			
NOTE.—A rock garden must have a cool exposure and a constant water supply. It should be made of large bowlders, with deep soil pockets. A stone pile in the hot sunshine is not a rock garden. In addition to the following, all the low perennials listed above are good in rock gardens.			
Adonis amurensis (Bird's-eye).......	Yellow.........	March–April	8 inches
*Aquilegias as given under *Good Foliage Perennials*, page 867.			

Herbaceous Perennials (*continued*)

	Color	Season	Height
Rock Garden Perennials (*continued*)			
**Aster alpinus*, and var. *alba*.........	Blue or white...	June......	6 inches
*Ferns: *Asplenium ebeneum*. *Polypodium vulgare*.			
Galax aphylla..................... A southern evergreen, with large, round, glossy leaves turning to a beautiful bronze in winter. Much used in floral decorations. Not hardy in all parts of New York State.	White..........	July.......	6 inches
Gypsophila cerastioides.............. A creeping plant, with large flowers (often $\frac{3}{4}$ inch across) and broad, downy foliage.	Pinkish white...	July.......	3 to 6 inches
**Gypsophila repens* .... A creeping plant, with small flowers and narrow, glabrous foliage.	Pinkish white...	June.......	3 to 6 inches
Hepatica triloba (Common Hepatica) Leaves three-lobed, evergreen.	White, lavender, or pink	April–May	4 to 6 inches
**Heuchera sanguinea* (Coral Bells)....	Brilliant red....	June–September	15 inches
Heuchera sanguinea var. *alba*........	White..........	June–September	15 inches
Lysimachia nummularia (Moneywort, or Creeping Charlie). Flat and creeping. Leaves opposite and evergreen, resembling those of *Mitchella repens* (Partridge Berry) but softer in texture and without the white midvein above.	Yellow	June.......	4 inches
**Œnothera missouriensis* (Missouri Evening Primrose). Prostrate habit. Bloom profuse.	Yellow.........	June–August	12 inches
Papaver alpinum (Alpine Poppy)	White..........	May–June..	6 inches
**Papaver nudicaule* (Iceland Poppy)...	White, yellow, orange, or red	May–October	12 inches
Potentilla tridentata................ Often woody at the base.	White..........	May–June..	6 to 8 inches
Saxifraga cordifolia................	Lilac-purple.....	April–May .	12 inches
Sedum acre (Stonecrop)............	Yellow.........	May–June..	2 to 3 inches
**Sedum spectabile* (Showy Stonecrop) For ordinary garden soil.	Lavender-pink..	September–October	18 inches
Sedum stoloniferum (Purple Stonecrop).	Purplish pink...	July.......	6 inches
Long-blooming Perennials			
**Achillea ptarmica*, The Pearl variety Foliage narrow and inconspicuous. Flowers abundant and persistent. An excellent plant for poor soil. (See page 871.)	White..........	June–September	$1\frac{1}{2}$ to 2 feet
**Anthemis tinctoria* var. *kelwayi* (Golden Marguerite).	Golden yellow..	June–September	2 to 3 feet

Herbaceous Perennials (*continued*)

	Color	Season	Height
Long-blooming Perennials (*continued*)			
Callirrhoë involucrata var. *lineariloba* (Poppy Mallow). Low and creeping.	Crimson, with white eye	June–September	12 inches
Chrysanthemum leucanthemum, Shasta Daisy variety.	White..........	June-August	1½ to 2 feet
Dianthus plumarius, Napoleon III variety (Napoleon III Pink).	Crimson........	June-August	12 inches
Gaillardia aristata..................	Yellow, with orange center (varieties range from yellow to crimson)	June–October	2 feet
**Heuchera sanguinea* (Coral Bells)....	Brilliant red....	June–September	15 inches
**Myosotis palustris* var. *semperflorens* (Ever-blooming Forget-me-not). Grows best where ground is moist and shady.	Blue...........	May-August	8 inches
**Papaver nudicaule* (Iceland Poppy) Flowers abundant. To be treated as an annual.	White, yellow, orange, or red	May–October	12 inches
**Phlox suffruticosa* (Early Phlox).....	Several colors, from Miss Lingard, white, to Burns, rosy purple	June–August	2 to 3 feet
**Viola cornuta* (Horned Violet, or Tufted Pansy).	White, yellow, blue, or purple	May–October	9 inches
**Viola tricolor* (Common Pansy)...... To be treated as an annual. (See note under *Hardy Annuals*, page 865.)	Many colors....	May–September	6 to 9 inches
Many-colored Perennials (Perennials with varieties in many colors)			
**Althæa rosea* (Hollyhock)...........	....	July–August	6 to 8 feet
*Chrysanthemums (Hardy Pompons)..	....	September–November	2 to 3 feet
*Crocus. (See under *Bulbs*, page 863.)..	....	March–April	6 inches
*Dahlias..........................	....	August–October	4 to 5 feet
**Dianthus barbatus* (Sweet William)...	....	June–July..	15 inches
*Gladiolus.......................	....	July–September	2½ to 3 feet
Hyacinths. (See under *Bulbs*, page 863.)	....	April–May..	12 inches
**Iris lævigata* [=*I. kæmpferi*] (Japanese Iris).	....	June–July..	3 feet
**Papaver nudicaule* (Iceland Poppy).. To be treated as an annual.	....	June–September	12 inches
*Peonies.........................	....	May–June..	2 to 3 feet

Herbaceous Perennials (*continued*)

	Color	Season	Height
Many-colored Perennials (*continued*)			
**Phlox paniculata* [= *P. decussata*] (Late Phlox).	....	July–September	3 to 4 feet
*Tulips:			
Early. (See under *Bulbs*, page 863.)	....	Late April–late May	12 inches
Late. (See under *Bulbs*, page 863.)	....	Middle May–early June	12 to 15 inches
**Viola tricolor* (Common Pansy)...... To be treated as an annual. (See note under *Hardy Annuals*, page 865.)	....	May–September	6 to 9 inches
Other Favorite Perennials for Flowers			
Asclepias tuberosa (Butterfly Weed)..	Bright orange...	July–August	1 to 2 feet
Aster lævis (Smooth Aster)..........	Light blue......	September–October	3 to 4 feet
**Bellis perennis* (English Daisy)...... Good for low border. Should be protected in winter with a light leaf mulch. Mainly grown as a spring bedding plant, to be renewed each year.	White, red, or pink	April–May..	6 inches
**Boltonia latisquama*...............	Pinkish lavender.	August–September	4 feet
Chrysanthemum coccineum [= *Pyrethrum roseum*].	White, pink, or red	June–July..	2 feet
**Coreopsis lanceolata* var. *grandiflora*.. Of strong growth, abundant in flower.	Deep yellow....	June–August	2 feet
*Dahlias...........................	All colors.......	August–October	4 to 5 feet
**Delphinium formosum*..............	Blue...........	June–July..	2 to 3 feet
**Dianthus barbatus* (Sweet William)...	White, red, or pink	June–July..	15 inches
Dicentra eximia..................	Rosy pink......	June–July..	18 inches
**Gysophila paniculata* (Baby's Breath).	Pinkish white...	July–August	2 to 3 feet
Helleborus niger (Christmas Rose).... Foliage evergreen. The first plant to bloom in spring.	White..........	February–March	6 inches
Liatris pycnostachya (Blazing Star, or Gay Feather).	Rosy purple....	August–September	4 to 5 feet
Papaver orientale (Oriental Poppy)..	Intense crimson.	June......	3 feet
Papaver orientale, Blush Queen variety	Crimson pink...	June.......	3 feet
**Papaver orientale*, Silver Queen variety	White..........	June.......	3 feet
**Physostegia virginiana* (False Dragonhead).	Pink, purple, or white	July.......	1 to 3 feet
**Platycodon grandiflorum*, and var. *album* (Balloonflower).	Blue or white...	July–September	2 to 3 feet
Primula polyantha (Polyanthus).....	Yellow, or mixed yellow and red	May.......	8 inches
**Pyrethrum roseum* [= *P. hybridum*] (See *Chrysanthemum coccineum*.)			
Rudbeckia speciosa (Coneflower).....	Yellow, with brown center	July–August	2 feet

Herbaceous Perennials (*continued*)

	Color	Season	Height
Other Favorite Perennials for Flowers (*continued*)			
Solidago cæsia (Blue-stemmed, or Woodland, Goldenrod). Slender and spreading. Grows best in partial shade. Flowers in axils of leaves.	Yellow.........	August–September	18 inches to 2 feet
Solidago canadensis................ Flowers in panicles. Root leaves present. A variety of this is often listed as Golden Wings.	Yellow.........	July–August	3 to 5 feet
Tall Grasses and Other Perennials for Bold Foliage Effects (See note relating to Cannas, under *Good Foliage Perennials*, page 868)			
NOTE.—*Penisetum japonicum* is an annual grass growing to 4 feet in height, and very desirable, especially for adding lightness to heavy foliage types.			
Arundinaria japonica (Japanese Bamboo). Foliage evergreen.	....	....	5 to 8 feet
Arundo donax (Giant Reed).........	....	....	8 to 15 feet
**Bocconia cordata* (Plume Poppy) .... Has large, handsome leaves, with a gray bloom resembling that of Bloodroot.	White.........	July–August	5 to 8 feet
**Erianthus ravennæ* (Wood Grass, or Plume Grass). Has long, violet-tinged leaves and handsome plumes, resembling the famous Pampas Grass.	....	....	4 to 7 feet
**Eulalia japonica* (Eulalia). (See *Miscanthus sinensis*.)			
**Hibiscus moscheutos* (Rose Mallow).. Has large, hollyhock-like flowers.	White, pink, or rose, with a darker center	August–September	4 to 6 feet
**Miscanthus sinensis* [= *Eulalia japonica*] (Eulalia). This and *Arundo donax* are the commonest ornamental grasses. There are three varieties: *gracillimus*, leaves narrow and green; *variegatus*, leaves striped; *zebrinus*, leaves banded.	....	....	4 to 9 feet
**Polygonum sieboldii* [=*P. cuspidatum*] An excellent foliage plant. Leaves broad heart-shaped; flowers small and white, in abundant lateral clusters.	White.........	August–September	5 to 6 fect
NOTE.—Buyers should be sure to get *P. sieboldii* [=*P. cuspidatum*], not *P. sachalinense*, which is larger and very rank in growth, spreads rapidly, and is almost impossible to eradicate.			

Herbaceous Perennials (*continued*)

	Color	Season	Height
Perennials Enduring Shade (See also *Woody Plants Enduring Shade*, page 854)			
NOTE.—All the plants under *Bulbs* will endure partial shade except Hyacinths, Tulips, and late Scillas. Lilies will also, except possibly *Lilium candidum*, but they should not be planted under trees. They thrive best among other perennials or shrubs. (For descriptions, see *Narrow Upright Perennials*, page 869.)			
For dry soil			
Ajuga genevensis (Geneva Bugle)...	Blue...........	May–June..	8 inches
**Aquilegia canadensis* (Columbine)..	Red and yellow..	May–June..	18 inches
*Ferns:			
Asplenium ebeneum (Ebony Spleenwort).	....	....	12 inches
Onoclea sensibilis (Sensitive Fern)	....	....	1 to 2 feet
Osmunda claytoniana...........	....	....	3 feet
Polypodium vulgare (Common Polypody).	....	....	6 inches
**Heuchera sanguinea* (Coral Bells)..	Red...........	June–July..	15 inches
Heuchera sanguinea var. *alba*...... These will grow in partial shade.	White..........	June–July..	15 inches
Iberis sempervirens (Evergreen Candytuft). Will grow in partial shade.	White..........	May–June..	12 inches
Liatris elegans..................	Rose...........	July–August	2 to 3 feet
Œnothera missouriensis........... For partial shade.	Yellow.........	June–July..	12 inches
**Rudbeckia fulgida*................ For partial shade.	Orange.........	August–September	18 inches to 2 feet
Rudbeckia triloba.................	Yellow.........	July–August	3 to 4 feet
Solidago cæsia (Blue-stemmed Goldenrod).	Yellow.........	August–September	1½ to 2 feet
Solidago speciosa................. Stout and spreading.	Yellow.........	September–October	3 to 4 feet
**Spiræa aruncus* [=*Aruncus sylvester*]	White..........	June–July..	4 to 6 feet
**Veronica rupestris*...............	Bluish purple...	May–June..	4 to 6 inches
For average moist soil			
**Aconitum autumnale* (Monkshood)	Blue...........	July–September	4 to 5 feet
**Anemone japonica*............... For partial shade.	Rosy pink and white	September–October	3 feet
Anemone ranunculoides...........	Yellow.........	April–May..	9 inches
Aster patens..................... For partial shade	Bluish purple...	September–October	18 inches
Campanula macrantha............	Purple.........	June.......	4 feet
**Convallaria majalis* (Lily of the Valley).	White..........	May–June..	8 inches
**Dicentra spectabilis* (Bleeding Heart) Grows best in partial shade.	Rosy pink......	May–June..	1½ to 2 feet
Dictamnus albus [= *D. fraxinella*] (Gas Plant). For partial shade.	White..........	June–July..	2 to 3 feet

Herbaceous Perennials (*continued*)

	Color	Season	Height
Perennials Enduring Shade (*continued*)			
For average moist soil (*continued*)			
Erythronium americanum (Adder's-tongue, or Dogtooth Violet).	Yellow.........	Late April into May	8 to 12 inches
Ferns:			
**Adiantum pedatum* (Maidenhair Fern).	....	....	12 inches
**Aspidium acrostichoides* (Christmas Fern).	....	....	12 inches
**Asplenium filix-fœmina* (Lady Fern).	....	....	2 to 3 feet
Lygodium palmatum (Climbing Fern).	....	....	2 feet
**Osmunda cinnamomea* (Cinnamon Fern).	....	....	4 feet
**Osmunda regalis* (Royal Fern)...	....	....	3 feet
**Funkia subcordata* (Day Lily)..... For partial shade.	White..........	August–September	1½ feet
Hemerocallis flava (Lemon Lily)... For partial shade.	Yellow.........	June–July..	2 to 3 feet
Hepatica triloba (Common Hepatica) Leaves three-lobed and evergreen.	White, lavender, or pink	April–May..	4 to 6 inches
Iris florentina..................... For partial shade.	White..........	May.......	18 inches
**Kniphofia* [= *Tritoma*] *pfitzeri* (Flame-flower). For partial shade. Should be mulched over winter, or, better, stored in sand.	Scarlet.........	August–September	3 to 4 feet
Liatris pycnostachya (Blazing Star, or Gay Feather). For partial shade.	Rosy purple....	August–September	4 to 5 feet
**Lobelia cardinalis* (Cardinal Flower)	Red...........	August–September	2 to 3 feet
Mertensia virginica (Bluebell, or Virginia Cowslip). For partial shade.	Blue...........	May–June..	18 inches
**Myosotis palustris* var. *semperflorens* (Ever-blooming Forget-me-not). Grows best in wet soil.	Blue...........	May–August	8 inches
**Nepeta glechoma* [= *Glecoma hederacea*] (Ground Ivy, or Gill-over-the-ground). Good ground cover.	Blue...........	April–May.	4 inches
**Platycodon grandiflorum*, and var. *album* (Bellflower, or Balloon-flower).	Blue or white...	July–September	2 to 3 feet
**Rudbeckia subtomentosa*...........	Yellow.........	August–September	4 to 5 feet
Solidago cæsia (Blue-stemmed Goldenrod).	Yellow.........	August–September	1½ to 2 feet
Spiræa palmata [= *Ulmaria purpurea*]. For partial shade.	Carmine-pink...	July.......	3 to 4 feet
**Trollius europæus* (Globeflower)...	Yellow.........	May–June..	12 to 18 inches

Herbaceous Perennials (*continued*)

	Color	Season	Height
Perennials Enduring Shade (*continued*)			
For average moist soil (*continued*)			
Tussilago farfara (Coltsfoot)...... Leaves resembling those of German Ivy (*Senecio mikanioides*) in shape, but much larger, dark green above and white downy below.	Yellow.........	April......	6 inches
**Viola tricolor* (Common Pansy).... For partial shade. To be treated as an annual. (See note under *Hardy Annuals*, page 865.)	Many colors....	May–September	6 to 9 inches
Perennials Enduring Poor, Dry Soil (Of many colors and sizes, from April to October, with an abundance of yellow in July, August, and September)			
For shade. (See *For Dry Soil*, under *Perennials Enduring Shade*, page 875.)			
For sunlight			
**Achillea millefolium* var. *rubrum* (Red Yarrow).	Red...........	July–September	2 feet
**Achillea ptarmica*, The Pearl variety	White..........	June–September	2 feet
Achillea tomentosa (Woolly Yarrow)	Yellow.........	June–September	6 to 9 inches
**Alyssum saxatile* (Golden Tuft)....	Yellow.........	April–May..	12 inches
**Anthemis tinctoria* var. *kelwayi* (Golden Marguerite).	Yellow.........	June–September	2 to 3 feet
Asclepias tuberosa (Butterfly Weed)	Orange.........	July.......	1 to 2 feet
**Cassia marylandica* (Wild Senna)..	Yellow.........	July–August	3 to 4 feet
**Coreopsis lanceolata* var. *grandiflora*	Yellow.........	June-August	2 feet
**Dianthus barbatus* (Sweet William).	Many colors....	June–July..	15 inches
Dianthus plumarius, Napoleon III variety (Napoleon III Pink).	Red...........	June-August	12 inches
Erigeron acris (Blue Fleabane)....	Purplish........	May.......	12 to 18 inches
Erigeron canadensis (Horseweed)...	White..........	June-August	2 to 3 feet
Helianthus rigidus, Miss Mellish variety (Stiff Sunflower).	Yellow.........	August–September	4 to 6 feet
Lamium album (White Variegated Nettle).	White..........	May-July...	6 inches
Lupinus perennis (Wild Lupine)...	Light blue......	June–July..	1 to 2 feet
**Lychnis coronaria*................	Bright crimson..	June–July..	18 inches to 2 feet
Lychnis coronaria var. *alba*........	White..........	June–July..	18 inches to 2 feet
Œnothera biennis var. *grandiflora* [= *Œ. lamarkiana*] (Lamark's Evening Primrose).	Yellow.........	June-August	4 to 5 feet
Œnothera speciosa (Showy Evening Primrose).	White..........	August–September	18 inches to 2 feet
Pentstemon diffusus (Beardtongue).	Light purple....	June.......	1 to 2 feet
**Phlox subulata*..................	Pink, white, or blue	April–May..	5 inches

Herbaceous Perennials (*continued*)

	Color	Season	Height
Perennials Enduring Poor, Dry Soil (*continued*)			
For sunlight (*continued*)			
Solidago nemoralis (Goldenrod).... Flowers in panicles.	Yellow.........	August–September	12 to 18 inches
Stellaria holostea (Easter Bell).....	White..........	May.......	12 inches
* *Veronica rupestris* (Rock Speedwell)	Bluish purple...	May–June..	4 to 6 inches
Hardy Aquatic Plants (See also *Woody Plants Enduring Wet Soil*, page 856.)			
For deep water (From 2 to 3 feet deep or deeper. Leaves mainly floating)			
Nymphæa [= *Nuphar*] *advena* (Spatterdock, or Yellow Water Lily). Will grow in any muddy water.	Yellow.........	June–August	
* *Nymphæa alba* var. *candidissima*... The best white Water Lily. Blooms the earliest of all and continues to bloom until frost.	White..........	June–August	
Nymphæa, American Hybrids (new forms mainly developed by William Tricker, of Arlington, New Jersey).	....	June–August	
* *Nymphæa marliacea* (Marliac's hybrids). These are old, well-known crosses made by M. Marliac, of Temple-sur-Lot, France, between *N. alba*, the common white English Water Lily, and *N. odorata* var. *rosea*, the Cape Cod Water Lily, and *N. flava*, the Yellow Water Lily of Florida. The following are four of the best hybrids: *albida*, dazzling white; *carnea*, beautiful pink; *chromatella*, clear yellow; *rosea*, brilliant crimson.	....	June–August	
Nymphæa odorata (Native White Pond Lily).	White..........	June–August	
Nymphæa odorata var. *rosea* (Cape Cod Water Lily). A beautiful, small Lily. Grows in cool water and does not bloom after hot weather.	Pink...........	June–July	
NOTE. — *Nymphæa zanzibariensis* (Zanzibar Lily) is an excellent tender Water Lily, in many colors. It grows readily from seed and should be treated as an annual.			
For shallow water (1 foot deep or less. Plants usually upright)			
**Acorus calamus* (Sweet Flag)......	....	....	2 to 3 feet

Herbaceous Perennials (*continued*)

	Color	Season	Height
Hardy Aquatic Plants (*continued*)			
For shallow water (*continued*)			
Butomus umbellatus (Flowering Rush). Leaves from 2 to 3 feet long, iris-like.			
**Calla palustris* (Water Arum).			
Carex lurida and C. vulgaris (Sedges).			
Decodon verticillatus [= *Nesæa verticillata*] (Swamp Loosestrife). Has arching stems, and narrow leaves with beautiful autumn color.			
**Iris lævigata* [= *I. kæmpferi*] (Japanese Iris).	Many colors except red	June–July..	2 to 3 feet
**Iris pseudacorus*................. From Europe.	Yellow.........	June.......	2 to 3 feet
Iris versicolor (Native Blue Flag) ..	Purple, marked with yellow and white	June.......	2 to 3 feet
Peltandra virginica (Arrow Arum)..	Flower greenish, foliage attractive dark green	....	2 to 3 feet
Pontederia cordata (Pickerel Weed) Has fine arrow-shaped foliage.	Purplish........	July–August	2 to 4 feet
Sagittaria latifolia [=*S. variabilis*] (Arrowhead).			
Typha latifolia (Cat-tail Rush) The spikes should be removed before the seed flies, and the plants should be kept within bounds by cutting them under water and pulling them out at the water's edge.	Brown.........	July–August	4 to 8 feet
For the water's edge			
Arundinaria japonica (Evergreen Bamboo).	....	....	5 to 8 feet
Arundo donax (Giant Reed)......	....	....	8 to 15 feet
Asclepias incarnata (Swamp Milkweed).	Rosy purple....	July–August	3 feet
**Aster cordifolius*................	Varying from white to lavender and rosy lilac	September–October	4 to 5 feet
**Aster novæ-angliæ* (New England Aster). The most beautiful and characteristic native fall-blooming plant.	Violet-purple to rosy purple	August–September	5 to 6 feet
Boltonia asteroides...............	White to lavender	September–October	5 to 7 feet
**Boltonia latisquama* (False Camomile). There is a variety *nana*, growing 2 feet high.	Pinkish lavender.	August–September	4 feet
**Caltha palustris* (Marsh Marigold) There is a double variety.	Yellow.........	April–May..	1 foot

Herbaceous Perennials (*concluded*)

	Color	Season	Height
Hardy Aquatic Plants (*continued*)			
For the water's edge (*continued*)			
Cornus canadensis (Bunchberry)... A native herbaceous cornel, with good foliage, white flowers, and red berries.	White..........	June.......	6 inches
*Eulalia. (See *Miscanthus sinensis*)			
Eupatorium perfoliatum (Boneset).	White..........	August–September	4 to 5 feet
Eupatorium purpureum (Joe-pye Weed). An excellent, strong-growing native plant, with immense, flat-headed, flower clusters.	Pinkish purple..	August–September	5 to 6 feet
*Ferns:			
Asplenium filix-fœmina.........	....	....	2 to 3 feet
Onoclea sensibilis..............	....	....	1 to 2 feet
Osmunda cinnamomea..........	....	....	4 feet
Osmunda regalis...............	....	....	3 feet
Helenium autumnale var. *superbum*.	Yellow.........	August–September	4 to 6 feet
**Hibiscus moscheutos* (Marsh Mallow).	White or rose...	August–September	4 to 6 feet
**Lobelia cardinalis* (Cardinal Flower)	Red...........	August–September	2 to 3 feet
**Lobelia syphilitica* (Blue Cardinal Flower).	Blue...........	August–September	2 to 3 feet
Lythrum salicaria var. *roseum superbum* (Purple Loosestrife).	Rosy purple....	July–August	5 to 7 feet
**Miscanthus sinensis* [= *Eulalia japonica*] (Eulalia). In three varieties, as follows: *gracillimus*, leaves narrow and green; *variegatus*, leaves striped; *zebrinus*, leaves banded.	... .	....	4 to 9 feet
Solidago canadensis .... Stem rather slender.	Yellow.........	July–August	2 to 3 feet
**Solidago sempervirens* .... Stem stout.	Yellow.........	August–September	4 to 6 feet
NOTE.—In all aquatic plantings the following plants should be rigidly excluded. They are rank in growth and easily become pests almost impossible to eradicate.			
Anacharis [= *Elodea*, or *Philotria*] *canadensis* (Water Weed).			
Limnathemum [= *Villarsia*] *nymphoides* (Floating Heart).			
Marsilea quadrifolia (European Marsilea).			
Nymphœa tuberosa (Tuberous Native Water Lily).			
Vallisneria spiralis (Eelgrass, or Tape Weed). This is also called Wild Celery, and is known to be a favorite food of the canvasback duck.			

Perennials in Order of Bloom

This list includes the bulbs and herbaceous perennials mentioned in the preceding lists, except those under *Long-blooming Perennials* and *Many-colored Perennials.* The dates are general only, and of value mainly because comparative. Local conditions and seasons greatly influence the time of bloom. The letter *w* before a name means *wild*—either native or escaped from cultivation. The varieties marked with an asterisk are especially desirable.

	Season	Height
March		
White:		
*Crocus	March–April	6 inches
**Galanthus nivalis* (Snowdrop)	March–April	6 inches
Helleborus niger (Christmas Rose)	February–March	6 inches
**Scilla sibirica* var. *alba* (Squill)	March–April	4 to 6 inches
Yellow:		
Adonis amurensis (Bird's-eye)	March–April	8 inches
*Crocus	March–April	6 inches
**Eranthis hyemalis* (Winter Aconite)	March–April	6 inches
Lavender:		
*Crocus	March–April	6 inches
Blue:		
**Scilla sibirica* (Squill)	March–April	4 to 6 inches
Purple:		
*Crocus	March–April	6 inches
April		
Hyacinths and early tulips begin to bloom in April, in all colors. (See under *Bulbs*, page 863); also Trailing Arbutus (*Epigæa repens*), pink, from late April into May. (See under *Woody Plants in Order of Bloom*, page 836.)		
White:		
Arabis albida (Rock Cress)	April–May	8 inches
**Bellis perennis* (English Daisy) White, red, or pink. (See under *Other Favorite Perennials for Flowers*, page 873.)	April–May	6 inches
(w) *Hepatica triloba* (Common Hepatica) White, pink, or lavender.	April–May	4 to 6 inches
**Narcissus poeticus*	April–May	12 inches
(w) **Phlox subulata*, The Bride variety	April–May	6 inches
Yellow:		
**Alyssum saxatile* (Golden Tuft)	April–May	12 inches
Anemone ranunculoides (Yellow Wood Lily)	April–May	9 inches
(w) **Caltha palustris* (Marsh Marigold) There is a double variety.	April–May	12 inches
(w) *Erythronium americanum* (Adder's-tongue, or Dogtooth Violet).	Late April into May	8 to 12 inches
**Narcissus pseudo-narcissus* (Common Daffodil).	April–May	15 inches
(w) *Tussilago farfara* (Coltsfoot)	April	6 inches
Red:		
**Bellis perennis* (English Daisy)	April–May	6 inches

Perennials in Order of Bloom (*continued*)

	Season	Height
April (*continued*)		
Pink:		
**Bellis perennis* (English Daisy)	April–May	6 inches
(w) *Hepatica triloba* (Common Hepatica)	April–May	4 to 6 inches
(w)**Phlox subulata* (Moss Pink)	April–May	6 inches
Lavender:		
(w) *Hepatica triloba* (Common Hepatica)	April–May	4 to 6 inches
Blue:		
Nepeta glechoma	April–May	4 inches
(w) *Phlox subulata* (Moss Pink)	April–May	4 to 6 inches
Purple:		
**Aubrietia deltoidea* var. *græca* (Purple Rock Cress). Dwarf and evergreen.	April–May	6 inches
Saxifraga cordifolia	April–May	12 inches
May		
Late Tulips begin to bloom in the middle of May. (See *Bulbs*, page 853.) Peonies bloom in late May and June, in many colors; the Chinese forms are the best, from 2 to 3 feet high. (See *Tree Peonies*, page 840.) German Iris (*Iris germanica*) also blooms in May and June, in all colors except pink and red, 3 feet high; also Pansies (*Viola tricolor*), Horned Violets (*Viola cornuta*), and Iceland Poppy (*Papaver nudicaule*). (See *Long-blooming Perennials*, page 872.)		
White:		
(w)**Convallaria majalis* (Lily of the Valley)	May–June	8 inches
**Iberis sempervirens* (Candytuft). Evergreen and excellent.	May	12 inches
Iris florentina (Orris Root). White, tinted lavender.	May	18 inches
(w) *Lamium album* (White Variegated Nettle)	May–July	6 inches
Papaver alpinum (Alpine Poppy)	May–June	6 inches
(w) *Potentilla tridentata*. Often woody at the base.	May–June	6 to 8 inches
Stellaria holostea (Easter Bell)	May	12 inches
Vinca minor var. *alba*	May	6 inches
Yellow:		
Primula polyantha (Polyanthus). Yellow, or mixed yellow and red.	May	8 inches
Sedum acre (Stonecrop)	May–June	2 to 3 inches
**Trollius europæus* (Globeflower)	May–June	12 to 18 inches
Red:		
(w)**Aquilegia canadensis* (Native Columbine). Red and yellow, mixed.	May–June	18 inches
Pink:		
Armeria maritima (Cushion Pink, or Thrift).	May–June	6 inches
**Dicentra spectabilis* (Bleeding Heart). Red and white, mixed. Thrives best in partial shade. An old-fashioned hardy perennial.	May–June	1½ to 2 feet

Perennials in Order of Bloom (*continued*)

	Season	Height
May (*continued*)		
Lavender:		
**Iris pallida* var. *dalmatica*. A beautiful and vigorous form.	Last of May–June	2 to 4 feet
Blue:		
Ajuga genevensis (Geneva Bugle)	May–June	8 inches
**Aquilegia cærulea*	May–June	18 inches
(w) *Houstonia cærulea* (Bluets). Pale blue.	May	3 to 6 inches
(w) *Mertensia virginica* (Bluebell, or Virginia Cowslip).	May–June	18 inches
(w)**Myosotis palustris* var. *semperflorens*. (See *Long-blooming Perennials*, page 872.)	May–August	8 inches
(w)* *Vinca minor* (Blue Myrtle). An evergreen trailing plant, excellent for ground cover in either sunlight or shade. There is a white variety.	May	6 inches
Purple:		
(w) *Erigeron acris* (Blue Fleabane)	May	12 to 18 inches
* *Veronica rupestris*	May–June	4 to 6 inches
June		
Japanese Iris (*Iris lævigata* [= *I. kæmpferi*]) blooms in June and July in many colors except red, 3 feet high. The plants are best grown in water. (See *Hardy Aquatic Plants*, page 879.) The flower is much larger than that of the German Iris. Shasta Daisy (Chrysanthemum), Early Phlox (*Phlox suffruticosa*), and Poppy Mallow (*Callirrhoë involucrata* var. *lineariloba*), also begin to bloom in June. (See *Long-blooming Perennials*, page 872.)		
White:		
Ægopodium podagraria var. *variegatum* (Variegated Goutweed). A common foliage plant used for edging	June	12 inches
(w)**Aruncus sylvester* (See *Spiræa aruncus.*)		
Aster alpinus var. *alba*. (See *Blue* for the type.)	June	6 inches
Astilbe japonica [= *Spiræa japonica*]	June–July	2 to 3 feet
Cerastium tomentosum. Foliage silvery.	June	3 to 6 inches
Chrysanthemum coccineum var. *album*. The white form of Pyrethrum. (See *Pink* for the type.)	June–July	2 feet
**Clematis recta*	June–July	2 to 3 feet
(w) *Cornus canadensis* (Bunchberry)	June	6 inches
**Dianthus barbatus* (Sweet William). White, red, or pink.	June–July	15 inches
Dictamnus albus [= *D. fraxinella*] (Gas Plant).	June–July	2 to 3 feet
**Digitalis purpurea* var. *alba* (Foxglove). This variety is better than the lavender type.	June–July	2 to 3 feet

Perennials in Order of Bloom (*continued*)

	Season	Height
June (*continued*)		
White (*continued*)		
(w) *Erigeron canadensis* (Horseweed)........	June-August....	2 to 3 feet
**Gypsophila repens*...................... A creeping plant, with small, pinkish white flowers and narrow, glabrous leaves.	June...........	3 to 6 inches
Heuchera sanguinea var. *alba*............ (See *Red* for the type.)	June–September.	15 inches
**Lilium candidum* (Madonna Lily)........	June–July......	3 to 5 feet
**Lychnis coronaria* var. *alba*..............	June–July......	18 inches to 2 feet
**Nymphæa alba* var. *candidissima* (Water Lily).	June–August ...	
Nymphæa odorata (Native White Pond Lily).	June–August....	
**Papaver orientale* (Oriental Poppy), Silver Queen variety. (See *Red* for the type.)	June...........	3 feet
Pyrethrum. (See *Chrysanthemum coccineum* var. *album*.)		
(w)**Spiræa aruncus* [= *Aruncus sylvester*].....	June–July......	4 to 6 feet
Spiræa japonica. (See *Astilbe japonica*.)		
Yellow:		
Achillea tomentosa (Woolly Yarrow)......	June–July......	6 to 9 inches
**Anthemis tinctoria* var. *kelwayi* (Golden Marguerite).	June–September.	2 to 3 feet
**Aquilegia chrysantha* (Yellow Columbine).	June-August....	3 to 4 feet
**Coreopsis lanceolata* var. *grandiflora*...... Bloom abundant. Growth vigorous.	June-August....	2 feet
Hemerocallis flava (Lemon Lily).........	June–July......	2 to 3 feet
Iris pseudacorus (European Yellow Flag)..	June...........	2 to 3 feet
(w) *Iris versicolor* (Native Blue Flag)........ Purple, marked with white and yellow. (See under *Purple*.)	June...........	2 to 3 feet
(w) *Linaria vulgaris* (Butter and Eggs)...... A bad weed, naturalized from Europe.	June–September.	1 to 2 feet
Lysimachia nummularia (Moneywort)....	June...........	4 inches
Nymphæa [= *Nuphar*] *advena* (Spatter-dock, or Yellow Water Lily.)	June–August....	
Œnothera biennis var. *grandiflora* [=*Œ. lamarkiana*] (Lamark's Evening Primrose).	June-August....	4 to 5 feet
(w) *Œnothera missouriensis* (Missouri Evening Primrose).	June-August....	12 inches
Orange:		
(w) *Hieraceum aurantiacum* (Hawkweed, or Devil's Paintbrush) A bad weed, naturalized from Europe.	June-September .	12 to 18 inches
Red:		
**Chrysanthemum coccineum* var. *rubrum*.... A red form of Pyrethrum. (See *Pink* for the type.)	June–July......	2 feet
**Dianthus barbatus* (Sweet William)....	June–July......	15 inches
Dianthus plumarius, Napoleon III variety (Napoleon III Pink).	June-August....	12 inches

Perennials in Order of Bloom (*continued*)

	Season	Height
June (*continued*)		
Red (*continued*)		
**Heuchera sanguinea* (Coral Bells)........ Brilliant red.	June–September.	15 inches
**Lychnis coronaria*......................	June–July......	18 inches to 2 feet
Papaver orientale (Oriental Poppy)...... Intense crimson.	June...........	3 feet
Pyrethrum. (See *Chrysanthemum coccineum* var. *rubrum*.)		
Pink:		
**Chrysanthemum coccineum* [= *Pyrethrum roseum*].	June–July......	2 feet
**Dianthus barbatus* (Sweet William)	June–July......	15 inches
(w) *Dicentra eximia*...................... Has a graceful habit and finely cut foliage.	June–July......	18 inches
**Gypsophila repens*..................... A creeping plant, with small, pinkish white flowers and narrow, glabrous leaves.	June...........	3 to 6 inches
Nymphæa odorata var. *rosea* (Cape Cod Water Lily).	June–July	
Papaver orientale (Oriental Poppy), Blush Queen variety.	June...........	3 feet
*Pyrethrum. See *Chrysanthemum cocineum*.)		
(w) *Spiræa lobata* [= *Ulmaria rubra* var. *venusta*] (Queen of the Prairie).	June...........	3 to 4 feet
Lavender:		
Digitalis purpurea (Foxglove)........... Pink-lavender; not so effective as the white variety.	June–July......	2 to 3 feet
Iris pallida var. *dalmatica* .... Clear blue-lavender.	Last of May–June	2 to 4 feet
Blue:		
Aster alpinus.........................	June...........	6 inches
Delphinium elatum	June-August....	4 to 6 feet
**Delphinium formosum* (Oriental Larkspur).	June–July......	2 to 3 feet
(w) *Lupinus perennis* (Wild Lupine).........	June–July......	1 to 2 feet
Purple:		
Campanula macrantha..................	June...........	4 feet
Dictamnus albus [= *D. fraxinella*] var. *rubra* Rosy purple.	June–July......	2 to 3 feet
(w) *Iris versicolor* (Native Blue Flag)........ Purple, marked with white and yellow.	June...........	2 to 3 feet
**Pentstemon diffusus* (Beardtongue).......	June...........	1 to 2 feet
July		
Hollyhocks (Althæa), Gladiolus, and Late Phlox (*Phlox paniculata* [=*P. decussata*]), begin blooming in July, in many colors. (See *Many-colored Perennials*, page 872.)		
White:		
**Bocconia cordata* (Plume Poppy).........	July–August....	5 to 8 feet
**Campanula carpatica* var. *alba*...........	July–August....	9 inches

Perennials in Order of Bloom (*continued*)

	Season	Height
July (*continued*)		
White (*continued*)		
**Campanula pyramidalis* var. *alba*	July–August	4 to 6 feet
(w) *Galax aphylla*	July	6 inches
Has evergreen leaves, bronzing in winter. Is much used in floral decorations. Not hardy in all parts of the State.		
Gypsophila cerastioides	July	3 to 6 inches
A creeping plant, with large, pinkish white flowers (often ¾ inch across) and broad, downy leaves.		
**Gypsophila paniculata* (Baby's Breath)	July–August	2 to 3 feet
Pinkish white.		
**Lilium brownii*	July–August	4 feet
White within, rosy violet without.		
(w) *Physostegia virginiana* (False Dragonhead)	July	1 to 3 feet
White, pink, or purple.		
Platycodon grandiflorum var. *album* (Bellflower, or Balloonflower).	July–September	2 to 3 feet
Stokesia cyanea var. *alba* (Stokes' Aster)	July–September	18 inches
(See *Blue* for the type.)		
Yellow:		
(w) **Cassia marylandica* (Wild Senna)	July–August	3 to 4 feet
(w) **Helianthus mollis* (Perennial Sunflower)	July–August	4 to 5 feet
Growth vigorous.		
Rudbeckia laciniata var. *flore pleno* (Golden Glow).	July–August	6 to 8 feet
Growth rank. Used too much. Color a crude yellow.		
(w) *Rudbeckia speciosa* (Coneflower)	July–August	2 feet
Yellow, with a brown center.		
(w) *Rudbeckia triloba*	July–August	3 to 4 feet
(w) *Silphium laciniatum* (Compass Plant)	July–September	5 to 6 feet
Rank in growth, like Golden Glow, but flowers a better yellow.		
(w) *Solidago canadensis* (Goldenrod)	July–August	3 to 5 feet
(w) *Solidago juncea* (Goldenrod)	July–August	3 to 5 feet
Flowers in panicles. Root leaves present, large and abundant.		
Orange:		
(w) *Asclepias tuberosa* (Butterfly Weed)	July–August	1 to 2 feet
(w) **Lilium tigrinum* (Tiger Lily)	July–August	4 to 5 feet
Orange, spotted purple.		
Red:		
**Achillea millefolium* var. *rubrum* (Red Yarrow).	July–September	2 feet
Pentstemon barbatus var. *torreyi* (Red Beardtongue).	July–August	4 to 5 feet
Pink:		
Gypsophila cerastioides	July	3 to 6 inches
A creeping plant, with large, pinkish white flowers (often ¾ inch across) and broad, downy leaves.		
(w) **Physostegia virginiana* (False Dragonhead)	July	1 to 3 feet
(w) *Sedum stoloniferum* (Purple Stonecrop)	July	6 inches
Purplish pink.		
Spiræa palmata [= *Ulmaria purpurea*]	July	3 to 4 feet

Perennials in Order of Bloom (*continued*)

	Season	Height
July (*continued*)		
Rose or rose-purple:		
(w) **Asclepias incarnata*	July–August	3 feet
Liatris elegans	July–August	2 to 3 feet
Lythrum salicaria var. *roseum superbum* (Purple Loosestrife).	July–August	5 to 7 feet
Blue:		
Aconitum autumnale Deep blue.	July–September	4 to 5 feet
**Campanula carpatica* (Carpathian Bluebell) Deep blue.	July–August	12 to 15 inches
**Campanula pyramidalis* (Steeple Bell-flower).	July–August	4 to 6 feet
**Platycodon grandiflorum* (Bellflower, or Balloonflower).	July–September	2 to 3 feet
**Stokesia cyanea* (Stokes' Blue Aster)	July–September	18 inches
Purple:		
(w) **Physostegia virginiana* (False Dragonhead)	July	1 to 3 feet
(w) *Pontederia cordata* (Pickerel Weed)... (See *Hardy Aquatic Plants*, page 879.)	July–August	2 to 4 feet
August		
*Dahlias bloom in August and through October. (See *Many-colored Perennials*, page 872.)		
White:		
Chrysanthemum [=*Pyrethrum*] *uliginosum* (Giant Daisy).	August–September	4 to 5 feet
(w) *Eupatorium perfoliatum* (Boneset)	August–September	4 to 5 feet
**Funkia subcordata* (Day Lily) An excellent plant for foliage.	August–September	18 inches
(w)**Hibiscus moscheutos* (White to rosy pink.)	August–September	4 to 6 feet
Lilium speciosum var. *album*	August–September	3 to 4 feet
(w) *Œnothera speciosa* (Showy Evening Primrose)	August–September	18 inches to 2 feet
Polygonum sieboldii [=*P. cuspidatum*] (Giant Knotweed). NOTE.—Buyers should be sure to get *P. sieboldii*, not *P. sachalinense*, which is larger and of very rank growth, spreading rapidly and being almost impossible to eradicate.	August–September	5 to 6 feet
Polygonum sieboldii var. *compactum*	August–September	18 inches
Yellow:		
(w) *Helenium autumnale* var. *superbum* Flowers golden yellow.	August–September	4 to 6 feet
(w) *Helianthus rigidus*, Miss Mellish variety	August–September	4 to 6 feet
(w) *Rudbeckia subtomentosa* (Sweet Cone-flower).	August–September	4 to 5 feet
(w) Solidago (Goldenrod): NOTE.—For early Goldenrods, see under *July*, page 886; for late, see under *September*, page 889		

Perennials in Order of Bloom (*continued*)

	Season	Height
August (*continued*)		
Yellow (*continued*)		
S. cæsia	August–September	1½ to 2 feet
S. lanceolata. Flowers in flat-topped clusters. Root leaves present.	August–September	3 to 5 feet
S. nemoralis. Good in poor gravelly soil.	August–September	12 to 18 inches
S. rigida	August–September	2 to 3 feet
S. sempervirens. Root leaves present.	August–September	4 to 6 feet
S. virgaurea var. *nana*. Low and compact. Root leaves present.	August–September	15 inches
Orange:		
**Lilium henryi*	August–September	4 to 5 feet
(w) *Rudbeckia fulgida*. Grows in partial shade.	August–September	18 inches to 2 feet
Red:		
**Kniphofia* [= *Tritoma*] *pfitzeri* (Flame-flower).	August–September	3 to 4 feet
(w) **Lobelia cardinalis* (Cardinal Flower). For a moist and shady location.	August–September	2 to 3 feet
Pink:		
(w) **Hibiscus moscheutos*. White to rosy pink.	August–September	4 to 6 feet
**Lilium speciosum* vars. *roseum* and *rubrum*.	August–September	3 to 4 feet
Lavender:		
(w) **Boltonia latisquama* (False Camomile). Pinkish lavender. There is a variety *nana*, 2 feet high.	August–September	4 feet
Blue:		
(w) **Lobelia syphilitica*	August–September	2 to 3 feet
Rosy purple:		
(w) *Liatris pycnostachya* (Blazing Star, or Gay Feather).	August–September	4 to 5 feet
Purple:		
(w) **Aster novæ-angliæ* (New England Aster). Violet-purple to rosy purple.	August–September	4 to 6 feet
(w) *Eupatorium purpureum* (Joe-pye Weed)	August–September	5 to 6 feet
**Statice latifolia* (Sea Lavender)	August	1½ to 2 feet
**Veronica longifolia* var. *subsessilis* (Speed-well).	August–September	2 to 3 feet
September		
The hardy old-fashioned *Button, or Pompon, Chrysanthemums, in many colors, begin blooming in September and continue through October and into November. They reach a height of from 2 to 3 feet.		

Perennials in Order of Bloom (*concluded*)

	Season	Height
September (*continued*)		
White:		
**Anemone japonica* (Japanese Windflower).	September–October	2 to 4 feet
(w) *Aster cordifolius*. White to rosy lilac.	September–October	4 to 5 feet
(w) *Boltonia asteroides*. White to lavender.	September–October	5 to 7 feet
Yellow:		
(w) *Helianthus giganteus* (Giant Sunflower)..	September–October	6 to 10 feet
Helianthus orgyalis (Narrow-leaved Sunflower).	September–October	8 to 10 feet
(w) *Solidago altissima* (Goldenrod).	September–October	7 to 9 feet
Solidago speciosa (Goldenrod).	September–October	3 to 4 feet
Red:		
**Anemone japonica* (Japanese Windflower).	September–October	2 to 4 feet
Rosy pink:		
**Anemone japonica* (Japanese Windflower).	September–October	2 to 4 feet
Lavender-pink:		
**Sedum spectabile* (Showy Stonecrop). One of the very best Sedums. Grows in ordinary garden soil.	September–October	18 inches
Lavender:		
(w) *Aster cordifolius*. White to rosy lilac.	September–October	4 to 5 feet
(w) *Boltonia asteroides*.	September–October	5 to 7 feet
Blue:		
(w) *Aster lævis* (Smooth Aster). Light blue.	September–October	3 to 4 feet
Ceratostigma plumbaginoides (Hardy Leadwort). Light blue.	September–October	9 inches
Clematis stans. Light blue.	September	4 to 5 feet
Purple:		
(w) **Aster patens*.	September–October	18 inches

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(Two accents are used in this index to indicate the accented syllable and the pronunciation. The grave accent (`) indicates the long sound of the vowel, the acute accent (ʹ) the shortened sound.)

NOTE.—The following errata should be noted. The words are misspelled in the text of the bulletin, but are corrected in the index.

Pages 871, 883. *For* Aster alpinus var. alba *read* Aster alpinus var. albus.
Pages 872, 883. *For* Callirrhoë *read* Callirhoë.
Page 811. *For* Cercidyphyllum *read* Cercidiphyllum.
Page 857. *For* Cotoneaster franchettii *read* Cotoneaster franchetii.
Page 817. *For* Evonymus radicans var. carrieri *read* Evonymus radicans var. carrierei.
Page 884. *For* Hieraceum *read* Hieracium.
Pages 818, 853. *For* Juniperus communis var. adpressa *read* Juniperus communis var. depressa.
Page 880. *For* Limnathemum *read* Limnanthemum.
Pages 842, 854, 859. *For* Rhododendron hinodegira *read* Rhododendron hinodegirum.
Pages 837, 842. *For* Rhododendron nudiflora *read* Rhododendron nudiflorum.
Page 813. *For* Sciadopytis *read* Sciadopitys.
Page 823. *For* Ulmus campestre *read* Ulmus campestris.
Page 840. *For* Viburnum alnifolia *read* Viburnum alnifolium.
Page 841. *For* Viburnum opulus var. sterilis *read* Viburnum opulus var. sterile.
Pages 853, 855. *For* Xanthorhiza *read* Xanthorrhiza.

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260 American varieties of beans
289 Lime-sulfur as a summer spray
291 The apple redbugs
295 An agricultural survey of Tompkins County
307 An apple orchard survey of Ontario County
313 The production of new and improved varieties of timothy
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341 Crop yields and prices, and our future food supply
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360 Variations in the tests for fat in cream and skimmed milk

CIRCULARS

9 Orange hawkweed, or paintbrush
12 The chemical analysis of soil
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16 The improved New York State gasoline-heated colony-house brooding system
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18 Milking machines: their sterilization and their efficiency in producing clean milk
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24 Some suggestions for city persons who desire to farm
25 Outline of the relation of the use of lime to the improvement of the soil
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JANUARY, 1912 (Reprinted in March, 1915) CIRCULAR No. 12

CORNELL UNIVERSITY

AGRICULTURAL EXPERIMENT STATION OF

THE COLLEGE OF AGRICULTURE

Department of Soil Technology

THE CHEMICAL ANALYSIS OF SOIL

E. O. Fippin

The large number of requests for analyses of samples of soils sent by residents of the State has made it advisable to put in printed form a statement of the policy of the College in this matter. There appears to be a general belief on the part of persons not familiar with the technic of soil investigation, that a chemical analysis of a soil is in itself a reliable guide to the fertilizer needs of that soil, to the kind of crops adapted to it, and to its general treatment. Unfortunately this is not the case. *It is the policy of this Department, therefore, not to make chemical analyses of samples collected by other than its own agents.* The insufficiency of a chemical analysis of the soil when unaccompanied by other careful studies, the unreliability of samples collected by persons not trained in the work, and the limited facilities of the College, make the analysis of miscellaneous soil samples an unprofitable expenditure of public money.

INSUFFICIENCY OF CHEMICAL ANALYSIS

Chemical composition of soils and plants.—Chemical analysis determines the total constituents, or some proportional amount of them, which a soil contains. The total amount of plant-food constituents in the normal soil is large in comparison with the amount removed by an average crop. Plants use ten elements in their growth, of which seven are obtained from the soil; the soil elements being iron, sulfur, magnesium, calcium, potassium, phosphorus, and nitrogen. Water and the carbon dioxide of the air furnish the other three elements—hydrogen, oxygen, and carbon.

Potassium, phosphorus, and nitrogen have been termed the fertilizer constituents because the addition of these most generally serves to give increased crop growth. The object of a chemical analysis of samples of soil is to determine whether any of these are present in insufficient amounts. The following table shows the amount of the most important plant-food constituents in a normal soil, in pounds per acre of soil one foot deep:

TABLE 1. Composition of Soil (in Pounds per Acre-foot)

	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
Normal soil	6,000	1,600	30,000	24,000	15,000

The quantities of the same constituents used by some of the common crops are shown in Table 2. They appear small in comparison with the amounts given in the first table.

TABLE 2. COMPOSITION OF CROPS (IN POUNDS PER ACRE)

	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
Corn grain, 50 bushels	50.0	8.5	9.5	1.0	3.0
Corn stover, 1.5 tons	24.0	3.0	26.0	10.0	5.0
Wheat grain, 25 bushels	35.5	6.0	6.5	1.0	2.0
Wheat straw, 1.75 tons	12.5	2.0	22.5	7.0	3.0
Clover hay, 2 tons	80.0	10.0	60.0	45.0	17.0
Potatoes, 150 bushels	32.0	6.5	45.0	2.0	3.0
Apples, 300 bushels	24.0	2.5	28.5	1.0	2.0
Apple leaves, 2 tons	30.0	3.5	27.0	50.0	13.0

The elements in the soil are chemically combined in the mineral particles and in the organic matter, and only a small proportion is in the soluble, or available, form at any one time. By a chemical analysis the total amount of any particular constituent present can be determined; but neither by this nor by any other laboratory determination can be indicated what part of this total is available to plants as the soil lies in the field.

Relation between chemical analysis and fertilizer response.—Experience covering many years, and on a great variety of soils, has shown that a laboratory determination of the availability of a soil is not often a reliable guide to the kind of fertilizer to which crops respond on that soil in the field. The deficiencies of certain constituents such as nitrogen and lime are frequently indicated by the physical characteristics of the soil. The absolute deficiency of other constituents is rare and does not warrant the College in making a chemical analysis in order to settle this point.

Other factors.—Several other factors may have much more influence on the productiveness of the soil than does the amount of plant-food contained. The moisture supply may be poorly regulated; there may be too much or too little at certain seasons. Lime may be needed to sweeten the land, organic matter may be deficient, the tilth may be bad. All these factors determine the availability to the crop of the food in the soil, and should first be adjusted so far as possible. This is necessary even when fertilizers are used.

UNRELIABILITY OF SAMPLES

A very small quantity of soil, only a fraction of an ounce, is used in chemical analysis. It is therefore of the utmost importance that samples for analysis be taken with the very greatest care in order that they may fairly represent the field or the farm. *Samples taken by an inexperienced person are very unlikely to be fairly representative.*

Samples for analysis should be taken by a person who is experienced in collecting such material and who knows the physical characteristics of the land. The geology of the region, the physical characters of the soil, the topography, the vegetation, the drainage conditions, and the past treatment with respect to crops, tillage, and manures, all determine the reliability of samples.

THE LIMITED FACILITIES OF THE COLLEGE LABORATORIES

The cost of making a chemical analysis of a soil is large, in time, in materials, and in equipment. To make a complete analysis requires the work of a highly trained chemist for about ten days. A complete determination on one sample alone therefore costs $20 to $50, according to the number run at one time.

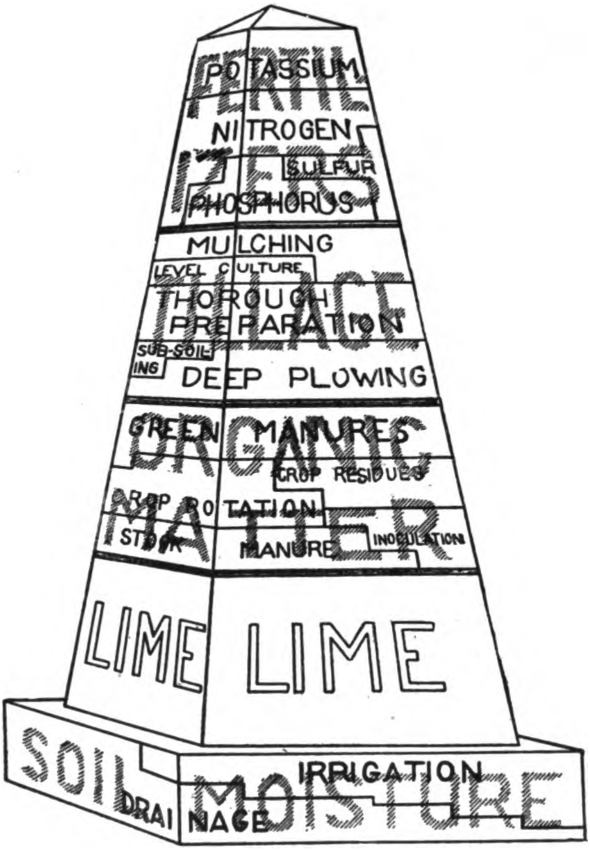

FIG. 1.—*Diagram representing the essential factors in a fertile soil in the order in which they should be adjusted, beginning at the base.*

The funds of the College for this purpose are very limited, owing to the many other lines of work that are being conducted.

In order that the results may be of the widest application, such funds as are available for the analysis of soils are believed to be best expended in systematic investigation of the chemical characteristics of samples of soil carefully selected by agents sent by the College, so that the samples are fairly representative of large areas. The supplementary data are collected in the same careful manner. This investigation of the chemical

character of the soil is part of a general investigation, now in progress, of the properties of, and the methods of handling, the soils of the State.

In considering the improvement of any piece of land, *the following factors should receive attention and must be properly adjusted* before either the natural store of food in the soil or the food added in fertilizers can be made most readily available to crops:

Moisture supply.—On a large part of the land in New York this requires some drainage—underdrainage by means of tile. It generally means careful surface tillage in order to enable the land to hold and conserve moisture, and on very light gravelly soil it may mean irrigation.

Lime.—For the majority of crops, and especially for the common legumes—clover and alfalfa—a sweet soil is necessary. Lime is used in order to bring about this condition, and is most likely to be needed on land long cultivated. If clover and blue grass do not thrive where sorrel and daisy are common, there is strong evidence of the need of lime.

A good supply of decayed organic matter, humus, indicated by a dark color, is essential to the normal New York soil. Stable manure and green manures give this condition.

Deep, careful plowing, thorough, clean, level tillage, and the use of the dust mulch on hoed crops, are essential. Where these conditions are fully met, the use of fertilizers is minimized and often rendered unnecessary.

The only reliable method of determining the fertilizer needs of a soil is by *field plot tests*, using different materials in different combinations for several years. Until such definite information is available, one must be guided in the selection of a fertilizer by the appearance of the soil and the characteristics of the crop to be grown. The safest policy is to use a complete fertilizer of a high grade. The composition most generally applicable is a fertilizer containing two to four per cent of nitrogen, nine to eleven per cent of phosphoric acid, and three to five per cent of potash. The quantity applied must be gauged by the value of the crop as well as by the condition of the soil. Crops of low value will warrant the application of only small quantities—one to three hundred pounds to an acre. Crops of higher value will warrant the use of correspondingly larger quantities of fertilizer.

The following books will be found to contain much useful information for the average farmer, on the character and composition of soils, fertilizers, and manures, and on the handling of the land:

Fertilizers and crops. By L. L. Van Slyke. Orange Judd Company. $2.50.

First principles of soil fertility. By Alfred Vivian. Orange Judd Company. $1.

Soil fertility and permanent agriculture. By C. G. Hopkins. Ginn & Co. $2.25.

Manures and fertilizers. By H. J. Wheeler. The Macmillan Company. $1.60.

CORNELL UNIVERSITY

AGRICULTURAL EXPERIMENT STATION OF

THE COLLEGE OF AGRICULTURE

Department of Animal Husbandry

Extension Service

THE CURING OF MEAT AND MEAT PRODUCTS ON THE FARM

K. J. SEULKE

The practice of curing meat has been followed for centuries. With each succeeding year new forms and varieties of cured meats are found on the market, but the principle underlying the process of curing is practically the same as at the beginning. The only difference is in the resulting flavor and appearance of the product and in the containers used, with a slight variation also in the ingredients.

The primary object in curing meats is to preserve them for future use, but their flavor and palatability may be improved at the same time. Meats that are unpalatable and unattractive in the fresh state may be ground, seasoned, and partially cooked; thus treated they are greatly improved in quality, and may have gained in digestibility although this is not always the case.

On the farm but few kinds of cured meats are used. Pork is practically the only meat treated in this way. The aim is too often merely to preserve the meat, and flavor and palatability are not considered. For the sake of variety, it would be well to spend a little time in curing meats other than pork. The object in presenting this circular is to discuss a few of the commoner cured meats and meat products, and to give directions for preparing them on the farm.

KEEPING FRESH MEAT

Since certain parts of the animal carcass are more valuable in the fresh state than when preserved, it may be well to consider the various methods of keeping fresh meat before taking up methods of curing.

All meat to be preserved, either fresh or cured, should be thoroughly cooled after the animal is slaughtered, for unless this is done the meat will not cure well nor will it be possible to keep it in a fresh state for any length of time.

In cold weather meat may be kept by hanging it in a dark, cool place, where dogs, cats, and rodents cannot reach it. If a temperature below 40° F. is maintained, meat may be kept for weeks; but with the temperature alternating between low and high, it will not keep well. Meat that is frozen will keep indefinitely so long as it remains frozen. Alternate freezing and thawing will spoil the flavor and cause early decomposition.

It is important that the meat be kept in a place where the air is dry. A dark, cool cellar, or an attic that is dry and free from odors, is the proper place for keeping meat on the farm.

Meat packed in snow may be kept for a considerable length of time. The meat should first be frozen hard. After it is frozen an earthen jar or a barrel should be provided, and a thick layer of snow should be tamped tightly in the bottom of this. On the snow a layer of meat is packed, and covered with another layer of snow. Care must be taken to have a thick layer of snow between the meat and the inner surface of the receptacle. Another layer of meat is then put on, and another layer of snow, and so on until all the meat is packed or the jar is almost full, when a heavy covering of snow should be put on top and covered with a block or some other object in order to keep out rats and mice. The meat may be taken out as needed, and the snow should be repacked on top each time.

Another method that is commonly used with pork and sausage is to partly cook the meat by frying it on both sides, pack it in a jar, and pour hot lard over it in order to seal the whole and keep out air. The meat may be taken out as needed. Care should be taken each time to melt the lard that is taken off, and to pour it back.

CURING MEATS

As has already been stated, meat should be thoroughly cooled before it is cured. It is equally important, however, that the meat shall not be in a frozen condition, for if it is frozen the brine or pickling solution cannot penetrate freely and the meat will not be of even flavor throughout.

Vessels

The vessels used for curing meats are of various sorts and sizes, depending on the amount of meat to be cured and the expense to which the owner cares to go.

Large earthen jars or crocks give the best results, but these are somewhat expensive — eight to ten cents per gallon of capacity — and they are very easily broken if not carefully handled.

Tight hardwood barrels may be used. New barrels or barrels that have contained molasses should be used, never vinegar or kerosene barrels unless they have been burned out on the inside. If molasses barrels are used they should be thoroughly scalded before using.

Chemicals used as preservatives

The principal preservatives used are salt, sugar, and molasses, and their combinations. Chemicals forbidden by law and those known to have a bad effect on health should not be used.

Salt preserves meat through its astringent and slightly germicidal action. It hardens the muscle fibers and draws the moisture from the meat.

Sugar and molasses have an almost opposite effect. They cause the retention of the moisture of the meat, and keep the muscle fibers soft and tender. Therefore salt and sugar are commonly used together, as

the sugar gives a desirable flavor and prevents the hardening action of the salt.

Saltpeter is often used to retain the natural reddish color of the meat. It is detrimental to health and should be used sparingly if at all.

DIRECTIONS FOR CURING MEATS

Pork

Sugar-cured hams, bacons, and tongues

Method I.— After the meat has been thoroughly cooled, the carcass may be cut up and cured. Sugar-cured pork is preferable to dry-cured pork or plain salt pork because of its pleasant flavor and because the meat is not so dry and hard. Beef tongues may be cured in the same pickle with the pork. All the pork carcass may be cured except the loins, which are used fresh for chops and roasts, the spareribs, which are used fresh, and the trimmings, which are used for lard and sausage. The hams, shoulders, and bacons are sugar-cured, and the fat backs are dry-cured or pickled in a plain salt pickle.

Before the meat is placed in pickle or salt, all corners and ragged edges should be cut off and used for sausage and lard. If they are left on they will be wasted, for they will be thoroughly soaked by the pickle and will be of no use.

Rub the pork thoroughly with salt and pack it in a cool place over night. The next day pack it in a barrel or an earthern jar, with the heaviest hams and shoulders at the bottom, the lighter hams and shoulders next, and the bacons and tongues at the top.

For every 100 pounds of meat weigh out 10 pounds of salt, 2½ pounds of brown sugar, and 2 ounces of saltpeter. Rub these together thoroughly, taking care that the saltpeter is finely powdered. Dissolve the whole by stirring it into 4 gallons of boiling water. Allow this brine to cool thoroughly, and then pour it over the meat. If it does not entirely cover the meat, add more water. The brine should cover the meat at all times. The meat may be weighted down with a block if necessary, for if it is not covered the projecting meat will decompose in a short time.

If the brine shows signs of fermenting during the curing process, it should be drawn off, boiled, and cooled, and then poured back on the meat.

The bacons and tongues may be taken from the pickle after four to six weeks, and after being washed in warm water they may be hung in the smokehouse and smoked. The lighter hams and shoulders will be ready to take out of the pickle in six to eight weeks, and the heavier ones at the end of the eighth week.

Method II.— Another recipe for sugar-cured hams, bacons, and tongues that has given good results is as follows:

Pack the thoroughly cooled meat in a cool, dry place, on a table that has previously been covered with a layer of salt. Sprinkle salt over each piece of meat, and add alternate layers of meat and layers of salt until all is packed.

Allow the meat to remain in the salt for eight to ten days, and then wash off the salt with lukewarm water. The meat is now ready to go into the pickle, which is mixed as follows: To 18 gallons of water add 5 pounds of brown sugar, a small handful of saltpeter, and 1 tablespoonful

of ginger. Stir the mixture until the solids are all dissolved, and then stir in 12 pounds of salt. Stir until all the salt is dissolved. This amount can be increased or decreased according to the amount of meat to be pickled. Ordinarily one fourth of this mixture will be enough for 100 pounds of pork.

The pickle should test 75° with the hydrometer test. If a hydrometer is not at hand, drop a fresh egg into the pickle; if the egg floats almost submerged, the brine is of the proper strength.

Pack the meat in a barrel or a jar, with hams and shoulders weighing over 10 pounds on the bottom, those weighing less than 10 pounds next, and the bacon strips and tongues on top. Pour the brine over the meat so that it is all covered, and weight it with a block so that none of the meat projects from the brine.

The bacons and tongues may be removed from the brine at the end of three weeks, the lighter hams and shoulders at the end of five weeks, and the heaviest ones after six to seven weeks. After the meat is removed from the brine it should be washed in warm water in order to remove the crust of brine and any scum that may have formed, and after drying for an hour or more it may be hung in the smokehouse and smoked.

Brine salt pork

Pack thoroughly cooled pork in a barrel or a jar after having rubbed each piece with salt. The following day weigh out for each 100 pounds of meat 10 pounds of salt and 2 ounces of saltpeter. Mix these, and dissolve the mixture in 4 gallons of boiling water. Allow this brine to cool thoroughly, and then pour it over the meat in the barrel. Place a block on top in order to keep the meat submerged.

Fat backs are ordinarily used for salt pork cured in brine, but any part of the carcass may be cured in this way. The meat cures best when cut in strips or in six-inch squares.

The meat should be left in the brine and be taken out as needed.

Dry-cured pork

To dry-cure meat involves more work than to brine-cure it, although it is a little less expensive in some cases. It is less difficult to merely salt the meat, pack in a jar, and pour the brine over it, than to rub the meat several times with the dry mixture. Also, the brine-cured meat is not so dry and is a little more palatable. Brine-cured meat can be kept anywhere as long as it is kept cool; dry-cured meat, on the other hand, should be kept in a cool, moist place, in order to insure even curing. With brine-cured meat there is no danger from rats and other vermin; but flies must be kept away from meat cured in either way.

In dry-curing pork, weigh out for every 100 pounds of pork 6 pounds of salt, 2½ pounds of granulated sugar, and 2 ounces of saltpeter, and mix thoroughly. Divide the mixture into three portions. Rub one portion on the meat the first day, and pack the meat in a barrel. Leave it for three days. At the end of the three days take the meat out of the barrel, rub it with a second portion of the mixture, and repack it. Three days later rub the meat with the third and last portion of the

mixture, and repack it. Let it stay in the barrel for ten to fourteen days. Then remove it, wash it in warm water, and smoke it.

Pickled pigs' feet

Take well-scraped pigs' feet, with the toes removed, and soak them in cold water over night. The next morning put them in a kettle, add enough water to cover them, and let them cook until soft. This will require about five hours. Salt should be added to the water during the cooking. When the pigs' feet are soft remove them from the water, split them, pack them in an earthen jar, and pour hot vinegar over them. Spices of various kinds may be added to the vinegar if desired.

Headcheese

Headcheese is made from the part of the head of the hog that would otherwise be wasted. When properly prepared it is a delicacy. The feet, as well as the head, may be used for this purpose.

Skin the hog's head, remove the eyes and the brain, and split the head through the midline, or down the center of the forehead and the nose. Usually the jowls are removed and salted. Put the head pieces into a cooker, add enough water to cover the meat, and boil the whole until the meat parts come readily from the bone. Remove the meat, separate it from the bones, and chop it finely. Remove the liquid from the kettle and save it for further use. After the meat is chopped return it to the kettle, pour on enough of the liquid to cover the meat, and allow it to cook for ten or fifteen minutes. While this final cooking is taking place, season the mixture with salt and pepper to suit the taste.

Put the cooked meat and the liquid that remains into jars, pans, or a cold meat press, place a weight on top, and allow the meat to cool. It will then be solid and can be sliced and eaten immediately.

Lard

Lard is made from the fat of the hog carcass. Three grades of lard are obtained from three parts of the body: the best grade, leaf lard, is made from the leaf, or layer of fat lying inside the abdominal wall; the second grade is made from the backs, the sides, and the pieces trimmed from the various cuts; the third and poorest grade is made from the intestinal, stomach, and pluck fats. The last is much stronger than the other two and should not be mixed with them. On the farm the first two grades are usually made together, and sometimes all three are made together.

Cut the fat into bits about one inch square, and trim out all particles of meat as they give an unpleasant burned flavor to the lard and are the first to scorch if the kettle become too hot. Put the pieces of fat into a kettle, and add a little water, not more than a quart, to keep the fat from burning until some of the lard has melted.

Keep the kettle hot until the cracklings are brown and rise to the top. Skim off the cracklings, and press out the lard that remains in them. Draw off the melted lard, and add a little baking soda to help whiten it. The lard should be stirred while it is cooling, in order to make it as white as possible.

Beef

Beef is not so commonly cured as pork; but when corned it takes the place of fresh beef during periods of the year when fresh beef does not keep well, and also offers a method of preserving part of the meat until it is needed and thus saving a waste or loss of meat, since it is impossible for one family to use an entire beef carcass in the fresh state. Dried beef commands a high price on the market. It also offers a method of preserving meat for future use. Jerked beef is made in the drier regions of the West. The climate of New York State is not dry enough nor warm enough to cure it successfully, and it is not so palatable as dried beef.

Corned beef

Method I.— Since corned beef is used for practically the same dishes as fresh beef, only wholesome, untainted meat should be used for this purpose. Naturally, the choicer the meat that is put into the pickle, the better will be the meat that comes out. The cheaper cuts of beef are ordinarily used for corning, because the choicer cuts are more palatable in a fresh condition. Plate, flank, shoulder, chuck, cross ribs, and rump are most commonly used for corning.

Frozen meat should not be put into the brine; neither should the brine be frozen while the meat is in it.

Weigh the meat. Cut it in pieces about six inches square. Place a layer of salt on the bottom of the vessel in which the meat is to be packed, cover this with a layer of meat, and sprinkle a layer of salt over the meat. Add alternate layers of meat and of salt until the meat is packed. Seven to nine pounds of salt will usually be enough for 100 pounds of meat. Allow the meat to stand in the salt over night. On the following morning make a brine, using 5 pounds of sugar, 2½ ounces of baking soda, and 3 ounces of saltpeter for every 100 pounds of meat. Dissolve these ingredients in 4 gallons of boiling water. Allow the brine to cool thoroughly before pouring it over the meat. If more or less than 100 pounds of meat are to be cured, use these proportions for the brine. If 4 gallons of brine does not entirely cover 100 pounds of meat, water may be added. The meat should be weighted down with a block or a clean stone, since any part that is not covered with the brine will decompose very quickly.

If the brine shows signs of fermentation in warm weather, it should be drawn off, boiled, strained through a clean cloth, and, after it is thoroughly cooled, poured back on the meat.

The brine should be kept in a cool, dark place. At the end of thirty days the meat will be ready for use. If the pieces are larger than six inches square, a longer time may be allowed, according to the size of the pieces.

Method II.— The same formula as is given under method II for sugar-cured hams and bacons may be used for corned beef also.

Pressed corned beef.— After the corned beef, prepared as described above, has been in the pickle for the required length of time, it may be taken out, and, after the brine is washed off, may be used in the same way as fresh beef. If desired, it may be made into pressed corned beef.

This is prepared as follows: Remove the beef from the pickling solution, wash it with warm water, and place it in a kettle. Keep it barely covered with water at all times, and boil it for two hours. Salt and pepper may be added while the meat is cooking, but usually there is enough salt in the meat from the brine. Take the meat from the kettle and pack it in pans or in a cold-meat press. Strain the broth through cheesecloth or muslin several times, replace it on the stove, boil it down to one half its original volume, pour it over the meat in the pans, and allow the whole to harden in a cool place. After the meat has hardened it may be sliced and eaten without further preparation.

Dried beef

Dried beef is usually made from the round, although any heavily muscled part may be used for this purpose. The inside of the round makes the tenderest meat. In cutting meat for dried beef, the muscles should be separated into their natural divisions. When cured and smoked in this way they can be sliced across the grain, and the meat is much tenderer than would otherwise be the case.

A jar or a barrel is the best receptacle in which to pack the meat when curing it. To each 100 pounds of well-cooled beef weigh out 6 pounds of fine salt, 3 pounds of granulated or brown sugar, and 2 ounces of saltpeter. Mix these thoroughly, without wetting, and divide the mixture into three portions. Set two portions away for future use, and rub the other portion into the meat. Pack the meat in the jar and leave it for three days. At the end of the three days take the meat from the jar, but leave in the jar the sirup that has formed. Rub the meat with another portion of the mixture, repack it, and leave it for three days. Remove it from the sirup, rub it with the last portion of the mixture, and repack it in the sirup in the jar. After three days remove the meat and hang it in the smokehouse, where it should be smoked until it is dry. It should then be kept in a dry place until it is used. The longer it is smoked and the drier it is kept, the longer it will remain good.

Pickled beef tongues

The recipe given for sugar-cured hams and bacons may be used also for pickling beef tongues.

Mutton and lamb

Mutton and lamb are seldom, if ever, cured on the farm. In the larger packing houses, mutton is sometimes partly cured in a plain salt pickle, and then cooked and packed in cans, which are soldered shut while the meat is still hot.

Domestic sausages

Sausage has been made for centuries. Its origin is said to have been traced to the ancient Egyptians. Whether this is true or not, at least it is known that centuries ago, in Europe, because of low wages and the high price of meat the poorer classes were compelled to use the cheaper grades of meat. These they soon learned to make into sausages of different

kinds, which were more palatable than the meat from which they were made and could be preserved for a considerable length of time.

Very good sausages can be made from the scraps that would otherwise be wasted in the butcher shop and on the farm. Such pieces as cheeks, trimmings, jowls, pork hearts and tongues, mutton hearts and tongues, and many other scraps that are seldom used fresh, will make a very palatable sausage and will serve for this purpose as well as any other meat.

Besides using scraps of meat and meat from poor and tough carcasses, the sausage maker also adds to his sausage such fillers as starch, potato flour, rice flour, corn meal, wheat flour, and buckwheat flour. The purpose of these fillers is to cut down the cost and the shrink, and to give a body, or solidity, to the sausage. This can be done on the farm if it is deemed advisable.

Preservatives

Preservatives of different kinds are used in the packing house, in order to prevent the decomposition of sausage meat when it is to be held for some time after it is ground and before it is put into casings or sold. On the farm this is seldom the case, and preservatives are not needed other than the salt and spices used in seasoning.

Hamburg steak

This is the simplest form of sausage made, and consists simply of fresh beef run twice through a grinder. It may be seasoned after the first grinding, or left unseasoned. It is never stuffed into casings. Any part of the beef carcass may be used for hamburg steak, but the best quality is made from the round.

Mixed sausage

This is made by mixing beef and pork in such proportions as to suit the taste of the consumer. This kind of sausage is usually made if the consumer dislikes the extremely fat undiluted pork sausage. It is seldom stuffed into casings, but is usually left loose and made into pats when fried. The following proportions of beef and pork give excellent results:

2 parts lean pork
3 parts lean beef
1 part fat pork

Pork sausage

Pork sausage should be made from clean, fresh pork scraps, or the cheaper parts of the meat. The meat should be in the proportion of three parts of lean pork to one of fat pork. This should be run through the grinder, spread out and seasoned with salt, pepper, and sage, and reground. Usually 1½ ounces of fine salt, ¾ ounce of ground black pepper, and ½ ounce or less of ground sage, for 6 pounds of meat, makes a satisfactory seasoning.

Pork sausage either is used loose, being made into pats and fried, or is stuffed into pork casings and double-linked. If left loose it can be packed in jars until used. If it is to be kept for a long period, it may

be run into cloth bags and smoked for a short time. The linked sausage may also be smoked for a short time in order to preserve it. If it is to be kept until summer, it may be partially cooked, packed in a jar, and covered with hot lard.

Bologna sausage

Bologna sausage is the commonest and most generally used type of sausage sold in America. It receives its name from the town of Bologna, in Italy, where it is said to have originated. It is common throughout Italy and all Europe, and this fact probably accounts for the quantities that are bought by Europeans in America. It is very palatable and is in demand in almost every locality. The ingredients used in making bologna sausage are wholesome and nutritious, but not especially palatable. This makes it economical to make, and the seasoning used makes it palatable. Many adulterations are commonly used in the making of bologna, and it is put up in a number of forms. The following formula gives only the most satisfactory ingredients and combinations used in its manufacture.

To eight parts of lean beef use one part of fat pork. Cut the meat into small pieces, mix, and grind. After the meat is ground the first time, spread it out and season with salt, pepper, and mace or ground coriander. Usually $1\frac{1}{2}$ ounces of fine salt, $\frac{3}{4}$ ounce of ground black pepper, and $\frac{1}{4}$ ounce of ground mace or ground coriander, for 6 pounds of meat, makes a satisfactory seasoning. After the spice is mixed in, regrind the meat and stuff it into casings. Bologna is stuffed either into beef rounds, middles, or bungs. If middles are used, the sausages are made ten to twelve inches long and left straight; if rounds are used, they are made fifteen inches long and the ends are tied together to form a ring; if bungs are used, they are made twelve to fifteen inches long and left straight. After the sausage is stuffed, it is allowed to dry for an hour and is then hung in the smokehouse and smoked for eight or ten hours. In smoking it is important to have as much smoke as possible and very little heat, for if the heat is too great the sausage will burst and be of no value. After smoking, the sausages are cooked for varying lengths of time, depending on the size, and are then hung on poles to dry. Cook long bolognas for twenty minutes at 155° F., round bolognas for twenty minutes at 155° F., and bung, or large, bolognas for one hour at 160° F.

Vienna sausage

Vienna sausage is a kind of sausage much liked by practically all classes of people. It is said to have originated in Vienna; hence its name. In America it is known under a variety of names, depending mainly on the size and style of packing and casings used.

To each two pounds of lean beef use one pound of fat pork. Chop the meat into bits and run it through a fine grinder. Spread the ground meat in a thin layer, and sprinkle it with salt, pepper, and mace, Other seasoning, such as sage, onions, or garlic, may be used if desired. Usually $1\frac{1}{2}$ ounces of fine salt, $\frac{3}{4}$ ounce of ground black pepper, and $\frac{1}{4}$ ounce of mace or sage, for 6 pounds of meat, makes a satisfactory seasoning. After the meat is seasoned, regrind it in order to mix the seasoning through

the meat thoroughly. If the meat does not seem fine enough, it may be ground a third time; for this sausage, like bologna, cannot be ground too fine. The meat is then stuffed into the casings. Casings of different size are used, depending on the size and kind of sausage desired. For midget vienna, or "high schools," use the very smallest sheep casings, and link the sausage in three-inch links. In linking vienna sausage or frankfurters, the casings are grasped with the thumb and the first finger of each hand, with the hands as far apart as it is intended to make the sausage long; then the fingers are pressed together until the meat is pressed out from under them, and the sausage between them is whirled, twisting the casing at the fingers. This is repeated until the entire casing is linked, the only variation being that the first sausage is whirled either toward or from the person linking, while the next is whirled in the opposite direction. This keeps the sausage from unlinking.

Ordinary frankfurters or large vienna sausages are made in exactly the same way, except that large sheep casings are used and the links are made five to six inches long.

For jumbo frankfurters pork casings are used and the links are made four to five inches long.

After the sausages are stuffed in casings they should be hung in the smokehouse and smoked for a sufficient time to give them a rich orange color. They are then taken out and cooked at a temperature of 155° for five to fifteen minutes, depending on the size. Care should be taken not to have too much heat in the smokehouse nor to have the water in which the sausages are cooked too hot; otherwise the sausages may split and the entire meat be wasted.

Blood pudding

Stir thoroughly a bucketful (3 gallons) of hog's blood until it is entirely defibrinated and the stringy fibers can be removed, leaving only the red liquid of the blood. To this liquid add 1 teaspoonful of saltpeter and 2 ounces of fine salt. After stirring these in, allow the blood to cool.

To 7 pounds of pickled beef's hearts and tongues (other parts of the beef may be used if these are not available) add 2½ pounds of fat pork. Cook these together for one half hour, remove them, run the lean beef through a fine grinder, cut the pork into bits ¼ inch square, and mix the beef and the pork. Stir the meat into the cold blood and add salt, pepper, and other spices. Usually 1½ ounces of fine salt and ¾ ounce of finely ground black pepper, for 6 pounds of meat, makes a satisfactory seasoning. If the mixture is not thick enough to stuff into casings, add enough finely ground corn meal to make it the consistency of thick mush. Mix thoroughly, stuff into beef bungs, and tie in fifteen- or eighteen-inch lengths. Cook the stuffed sausages at a temperature of 160° for an hour and a half, or until a sharp stick or pin can be run into the center — not through the sausage — and withdrawn without being followed by any blood. Lay the sausages on a table so that they may become solid, and turn them over after a half hour. After they have cooled until they are solid they are ready for use. If they are to be kept for any length of time they should be smoked for eight to ten hours.

Scrapple

Scrapple is usually made from the heads and the feet of hogs, but it may be made from any part of the pork carcass. If heads are used, split them through the center, place them in a cooker or a kettle with enough water to cover them, and cook them until the meat separates from the bone. Take out the meat and the bones, and save the broth for future use. Pick all the bones from the meat, chop the meat finely, add this to the broth, and replace the whole on the stove to boil. Add enough corn meal (ground fine) and buckwheat flour to the broth, in the proportion of 9 parts of corn meal to 1 part of buckwheat flour, to make it as thick as mush. The meal and the flour should be mixed dry, and added gradually while the broth is being stirred, in order to prevent lumpiness. Stir the mixture for fifteen minutes and then allow it to cook slowly for an hour, when it should be of the consistency of thick mush. Pour the scrapple into shallow pans and allow it to cool. It can then be sliced and fried.

Sausage casings

Casings are made from the intestines of sheep, hogs, and cattle, and are thoroughly cleaned and prepared before being used. Sausage casings may be bought ready for use at a fairly reasonable price, or they may be cleaned on the farm. Sheep casings are used for vienna sausage (wienerwurst) and for frankfurters. Pork casings are used for pork sausage, liver pudding, and jumbo frankfurters. Beef rounds, made from the small intestine, are used for bologna; beef bungs, made from the large intestine, are used for large bologna and for ham sausage; beef middles are used for bologna and for summer sausage.

To clean sausage casings, empty them and wash them inside and outside, and soak them in a solution of lye or some other alkali water. Then turn them and scrape them both inside and outside, to remove the slime and the fat. Wash and re-turn them, and pack in salt until needed.

SMOKING MEATS ON THE FARM

The smoking of cured meats aids in their preservation because the smoking process closes the pores of the meat or casings, and the creosote is objectionable to some insects.

Smoking gives a desirable flavor to the meat if the proper kind of fuel is used. Green hickory is best, but other hardwoods or corncobs may be used if hickory is not available. Resinous woods should never be used, as they give an objectionable flavor to the meat. Corncobs are commonly used, but are not so satisfactory as hickory because of the fine ash that is forced upward by the heat and settles on the meat, giving it a dirty appearance. Juniper berries and fragrant woods are sometimes added to the fire, to give desired flavors.

Proprietary smoking preparations are not to be recommended, as a whole, because they hasten the curing process and do not give as desirable a flavor as does the ordinary smoking process. Some of these preparations also contain substances that cause digestive disorders when the meat

is eaten. This is especially true of the various dips used to take the place of smoking.

The smokehouse

The smokehouse may be of any size or construction, to suit the needs of the owner. If the house is to be used only once and only a small amount of meat is to be smoked, a large barrel or a dry goods box may be used. If the house is to be permanent, it is often worth while to build it of brick, concrete, or stone, in order to avoid all risk of loss by fire. A frame house may be used, provided that care is taken to confine the fire to the center of the floor, or to build it in a large iron kettle, so that it will not spread to the house. The safest method of smoking meat, and at the same time of preventing the smokehouse from getting too hot, is to dig a small furnace pit in the ground about ten or twelve feet from the smokehouse, and have the smoke carried from this to the house through a galvanized pipe laid on top of the ground and covered so that it will not be crushed.

The method of construction of the smokehouse should allow ample ventilation, and there should be some means of regulating the draft. This can be done by having the outlet for the smoke under the eaves and the intake for the air at the furnace, if this is used; or, if the furnace or outdoor fire method is not used, an adjustable air intake may be attached to the door and covered with a heavy screen to keep out flies and rats.

For ordinary farm use, the house should be about eight feet square and eight to ten feet high, so that the meat will hang six to seven feet above the fire and near enough to the roof to get the benefit of the thick smoke and yet be below the level of the ventilators.

The smoking process

Meat that has been pickled should be removed from the brine at least a day before it is to be smoked, and after being washed in warm water it should be hung up to dry until it is ready to smoke. The meat should be hung in the smokehouse, with no two pieces touching each other, and then a fire should be started, heating the house gradually. The meat should be kept warm, but not hot enough to dry the outside too much and prevent the smoke from penetrating. There should be as much smoke as possible, but no more heat than is necessary.

In winter the fire should be kept burning constantly until the smoking is completed, for if the meat is allowed to cool too much the smoke will not penetrate it. Meat that has been frozen should not be put into the smokehouse until it is thawed.

In warm weather there is danger of getting the meat too hot, and for this reason it is good practice to let the fire die down every other day until the meat has become properly smoked.

After the meat has become properly colored it should be cooled (but not allowed to freeze) by opening the ventilator or the door, leaving it open until the meat hardens. It may then be packed away for future use.

The meat may be kept in the smokehouse for a time if the weather is not too warm, but the house should be kept free from flies.

If the smoked meat is to be used immediately, no further care is needed; but if it is to be held until summer it should be wrapped in clean, white

paper, and a covering of muslin sewed on to protect it from insects. It should be kept where it will not be subject to extreme change of temperature or to dampness.

If the meat is to be kept for a considerable length of time and absolute safe-keeping is desired, the following directions, given by the United States Department of Agriculture in Farmers' Bulletin No. 183, page 37, should be followed:

" For absolute safe-keeping for an indefinite period of time, it is essential that the meat be thoroughly cured. After it is smoked and has become dry on the surface it should be wrapped in parchment paper; or old newspapers will do where parchment cannot be had. Then inclose in heavy muslin or canvas, and cover with yellow wash or ordinary lime whitewash, glue being added. Hang each piece out so that it does not come in contact with other pieces. Do not stack in piles.

" Recipe for yellow wash.—For 100 pounds hams or bacon take

3 pounds barytes (barium sulphate)
0.06 pound glue
0.08 pound chrome yellow (lead chromate)
0.40 pound flour

" Half fill a pail with water and mix in the flour, dissolving all lumps thoroughly. Dissolve the chrome in a quart of water in a separate vessel and add the solution and the glue to the flour; bring the whole to a boil and add the barytes slowly, stirring constantly. Make the wash the day before it is required. Stir it frequently when using, and apply with a brush."

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THE COLLEGE OF AGRICULTURE

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APPLE CANKERS AND THEIR CONTROL

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Cankers in apple trees are a constant source of danger because of the fact that they persist from year to year and are likely in time to cause the death of a large limb or a tree. Ordinarily any disease that is not controlled by the regular schedule of spraying is left to take its annual toll, and its treatment becomes a secondary matter until the total damage attracts more than usual attention. Cankers are present in every fruit-growing region of the State; they are more prevalent in certain sections than in others, however, depending on such factors as weather and orchard management.

The term *canker*, like most common names of plant diseases, is somewhat loosely used. It is ordinarily applied to a diseased condition of woody plants in which the bark is killed in a more or less definite area. The dead part is usually sunken, although adjoining regions of the stem may become enlarged subsequent to the killing.

KINDS OF CANKERS

In New York State there are a number of different kinds of cankers on the apple tree. Named in order of their importance they are: frost cankers, New York apple-tree canker (caused by *Physalospora cydoniæ*), fire-blight canker (caused by *Bacillus amylovorus*), the so-called European apple-tree canker (caused by *Nectria ditissima*), and the Illinois blister canker (caused by *Nummularia discreta*)—the last-named occurring only to a limited extent. The bitter-rot canker (caused by *Glomerella cingulata* of the Middle West) is of rare occurrence in New York. A superficial bark canker (caused by *Myxosporium corticolum*) is very common on apples, pears, and quinces, but does no material damage.

To the casual observer the various cankers are somewhat similar in appearance and in general effect on the trees. They involve primarily the bark, rarely penetrating the wood to any extent. The blister canker and the New York apple-tree canker, however, attack the wood.

Frost cankers

In certain severe winters frost is a very active agent in the production of cankers. An examination of apple trees after such winters shows many irregularities as to the extent of injuries in orchards differently

located and managed. Some varieties—as, for example, Tompkins King, Twenty Ounce, and possibly Hubbardston—are uniformly more susceptible than others. On the other hand, varieties that are normally less susceptible may suffer serious injury under sudden and extreme temperature changes in winter.

FIG. 1.— *Baldwin tree with frost cankers in the crotches of the main limbs*

Branch cankers resulting from the action of frost are commonly termed *sun scald*. The name *sun scald* has arisen out of the fact that this type of frost injury is almost always found on the southwest side of the tree and has been ascribed to the action of the sun in warming the tissue after a severe cold period. It is difficult to say just how the canker arises, but it seems that there is some interaction of cold with heat from the sun, and that the injury is dependent on a peculiar set of climatic factors not fully understood.

Frost cankers are a serious problem with which apple growers have to contend, since the initial injury is so frequently followed by fungi that irritate and extend the wound. The cankers form chiefly on the trunk or at the crotches of main branches (Fig. 1). Similar injuries occur at the base or the crown, and in these cases the injury is called *crown rot*, *collar rot*, and so forth. It is a well-known fact that the Tompkins King variety suffers seriously from these cankers. In all the above cases the injured bark becomes discolored, dead, and loosened from the tree, often sloughing off and exposing the wood.

FIG. 2. — *Twenty Ounce limb showing young New York apple-tree canker. The bark is slightly sunken and discolored, and the diseased area is bounded by a crevice. Note that the surface is still smooth*

New York apple-tree canker

The New York apple-tree canker disease is found on the limbs as a canker, on the fruit as a black rot, and on the leaves as a leaf spot. It is caused by a fungus which promptly follows frost, fire blight, and other injuries, and is readily transmitted from one part of the tree to another.

It is found on many wild plants and may pass from these to the apple, obviously making its occurrence more serious.

The cankers usually form on the larger limbs, although not infrequently the trunk and the twigs are affected. During the growing season young

cankers may be observed more commonly on the upper surface of the branches. Careful examination will usually show that the canker originated in a wound of some sort. The bark is at first of a reddish brown color and slightly sunken (Fig. 2). The diseased area increases in size and becomes darkened, and after a few weeks the canker is longer in the diameter parallel to the main axis of the branch. Many cankers remain small, measuring only a few inches in diameter, and may die out at the end of the growing season; but in severe attacks the spot spreads from year to year for a distance of several feet. In some cases there is only a superficial roughening, while in others the bark is killed to the wood and soon becomes conspicuously cracked. The margin of the canker is at first rather indefinite, being distinguished from the healthy bark only by its darker color; but later a deep crack or crevice is formed, which seems to temporarily limit the further spread of the canker-producing organism. After a time the crevice may be traversed, and the fungus subsequently continues its invasion until a second crevice obstructs it. This process is repeated from one or more points along the margin of the canker until a series of somewhat concentric regions are developed (Fig. 3). The bark remains closely appressed to the wood for a year or more (Fig. 4), finally falling away and exposing the wood as well as a callus along the margin. On those spots that begin earlier in the season, numerous scattered pustules, the spore cases of the fungus, appear (Fig. 5).

FIG. 3.— *Young New York apple-tree canker, showing characteristic, somewhat concentric, rings*

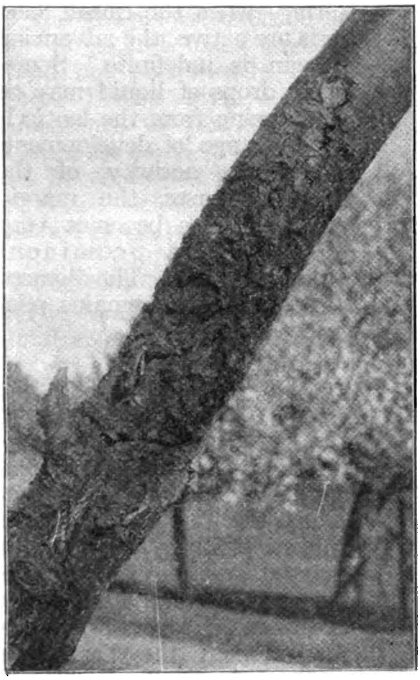

FIG 4.— *Typical older New York apple-tree canker. The bark is dead and very much roughened*

As stated above, the canker fungus develops on the leaves and the fruit. Spots on the foliage appear most abundantly with the opening of the

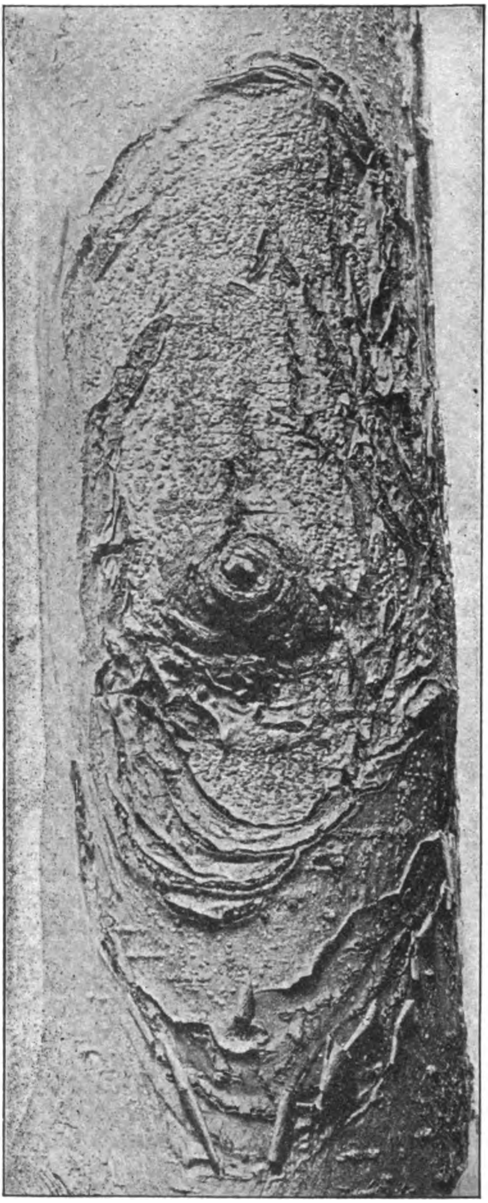

FIG. 5.—*New York apple-tree canker as it appears the first year or two. On the surface of the canker are seen numerous scattered pustules, the spore cases of the fungus*

leaves and in July and August. They begin as minute purplish specks, soon enlarging to about one-eighth of an inch in diameter and turning brownish. The black-rot form of this disease on fruit is common on early fall varieties and on windfalls. The disease begins either at the blossom end or at some wound, commonly following codling-moth injury. The fruit is reduced to a black mummy and is covered with the pustules, as described for the canker form of the disease.

Fire-blight canker

The fire-blight canker disease is found on the bark of the trunk or the larger limbs, where it appears in the form of a canker (Fig. 6). In the spring, when the causal bacteria are active, the advancing margin is indefinite. Sometimes drops of liquid may be seen oozing from the lenticels at this stage of development. When the activity of the bacteria ceases, the margin of the canker becomes very definite and a prominent crevice marks it. The diseased bark sinks and remains relatively smooth.

European apple-tree canker

Like other apple cankers, the European apple-tree canker begins as a slight discoloration on the bark, and very soon the area affected is sunken. Later, however, a marked swelling appears immediately above and below the diseased spot. Within a few months the bark falls away and a callus is formed about the margin of the canker. This seems to prevent temporarily the

progress of the causal fungus, but the callus layer is later penetrated and the injury is thus enlarged. This process is repeated successively until the canker finally appears as a large wound within which is a series of these concentric calluses (Fig. 7).

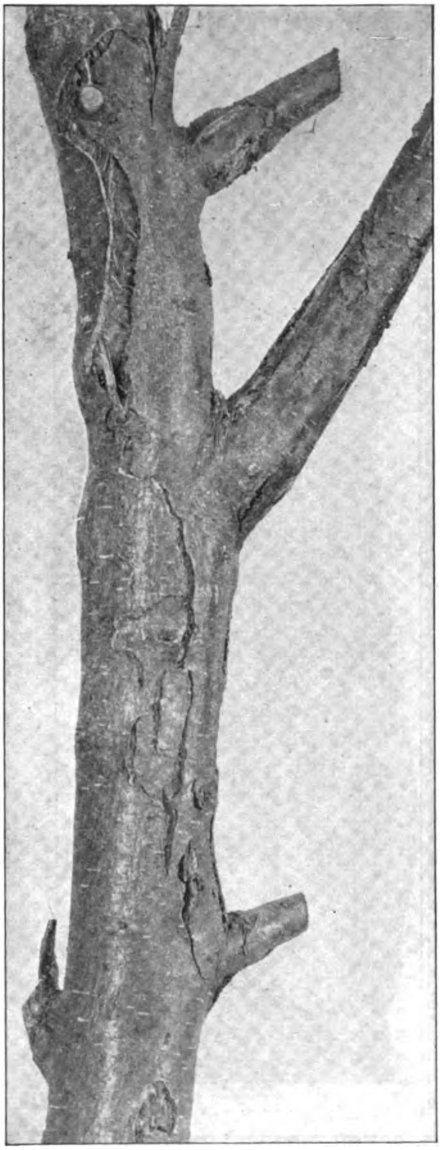

FIG. 6.—*Fire-blight canker. Note the crevice and the smooth surface of the canker*

Illinois blister canker

The Illinois blister canker has been found in New York and may have a widespread distribution. It is a fungous disease usually found on the larger limbs and the trunks and affecting bark and wood. The diseased bark is at first brown and slightly sunken, and shows healthy bits of tissue scattered within the general diseased area. In a later stage the bark becomes much roughened and blackened and falls off in irregular patches, exposing the wood. On the dead areas, or often on bark before it falls off, are developed the fruiting parts of the fungus (stromata), which are large and black and which stand out prominently (Fig. 8). These bodies give a blistered appearance to the affected part, whence the name. This canker cannot be controlled by the methods suggested below. A satisfactory method of control is not known.

CANKER CONTROL

The control of cankers has been a matter of consideration for some time, but the removal of dead limbs, supplemented in certain cases by the regular schedule of sprayings, is usually the extent of the efforts made to thwart these diseases. It is obviously absurd to delay treatment until the affected organ has been killed. Measures to remove the cause before it has gone so far seem more rational, since spraying has not proved sufficient.

Canker treatment may be followed along one of two lines: the affected limb may be cut from the tree, or the diseased bark may be removed.

No prescription can be given, except in a general way, as to which method to follow. Each case must be studied by the grower and the procedure should be in accordance with the conditions; the producing power of the tree or the limb concerned should be the criterion. But whether the limb is removed or the canker cut out, a wound will result, and the application of a dressing becomes essential.

FIG. 7.—*Typical European apple-tree canker, showing layers of callus on the wound*

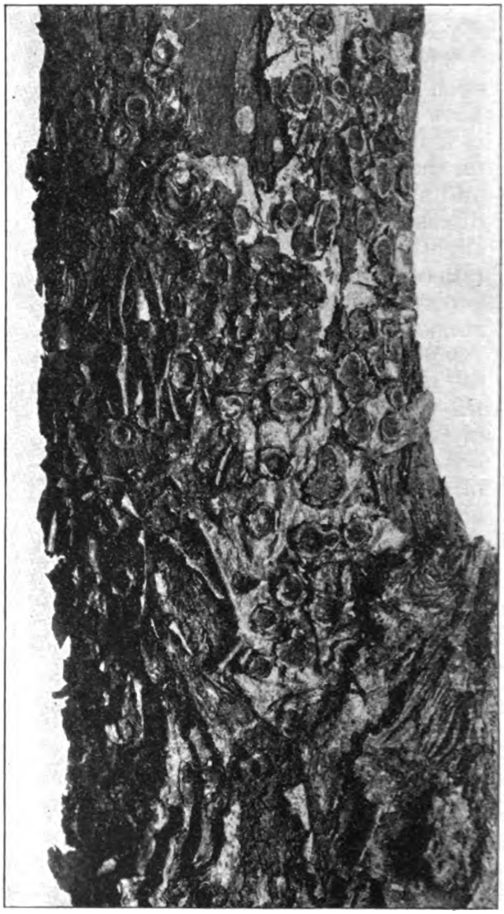

FIG. 8.—*Illinois blister canker, showing stromata on the cankered surface*

Removing affected branches

In the removal of cankered limbs the cut may be made so that another limb, or water sprout, can grow in the approximate space left by the part removed. This method, supplemented by careful spraying of the bark, is successfully practiced in a Twenty Ounce orchard in the Lake Ontario belt.

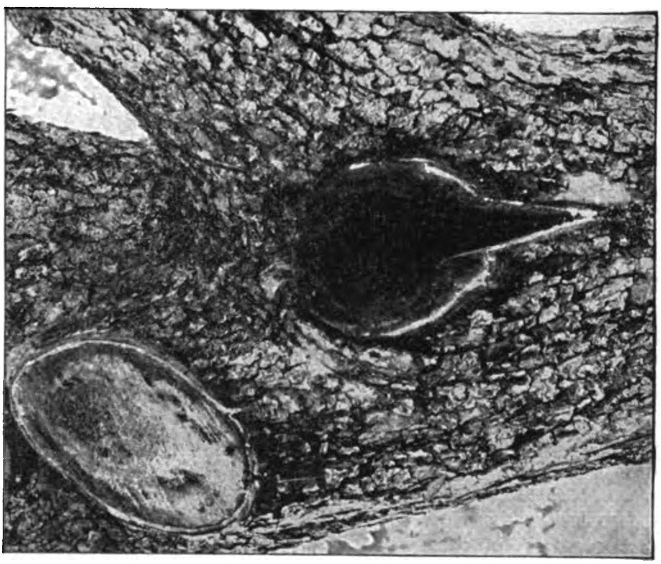

FIG. 9.—*A method of treating heart rot. After removal of the diseased tissue, a V-shaped cut is made as illustrated*

FIG. 10.—*Stub left by the improper removal of limb. Such a cut surface can never heal*

Grafting of stubs left by the removal of the affected part of the limb is a method used on some trees. This may be justified in certain cases, but it also must be supplemented by careful spraying of the bark.

If the limb is removed, the cut should be at the junction of the limb with the parent branch. The cut should be made close to and perfectly even with the outline of the parent branch, without regard to the size of the resulting wound (Fig. 9). It is important that the cut be smooth, for on this condition depends the fate of the wound so far as healing is concerned. A rough, splintered surface may be avoided by the following well-known method: Two cuts are made, one at some distance, at least two feet, from the base of the branch, the other at the base. The first cut is made by sawing partly through the limb from the lower side, then completing the operation by sawing from the upper side; this prevents splitting and tearing of the bark and the wood. The second cut, which is the final one, is then made at the base of the branch, and the wound is smoothed with a mallet and chisel.

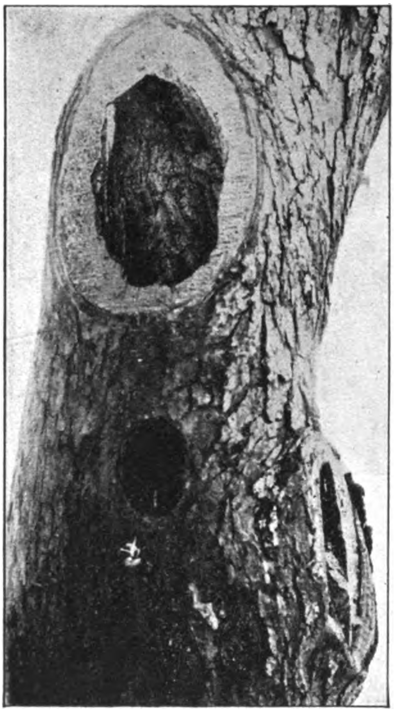

FIG. 11.— *Another method of treating heart rot in a limb. The decayed wood is removed and a hole is bored at the lower end of the diseased part to serve as a drain*

It is not a good practice to leave a stub projecting from the trunk, as shown in figure 10. Such a cut surface can never heal. It is not even advisable to leave a stub only a few inches in length. In such cases the process of healing is necessarily much longer; indeed the exposed surface may never be covered by a callus, and if the cut is left without the protection of a wound dressing or a callus, heart rot is almost sure to result. Where orchard practice has been such that cavities and decayed hearts are present, a few simple operations now may obviate the necessity of heavy expenditure of time and money in the future. It requires comparatively little time and expense to clean and paint a fresh injury or decay in its early stages. It often requires much time and expense to treat properly the same injury after it has been neglected for a few years.

It should be borne in mind that the heart of a tree is practically dead tissue; it gives only rigidity, and may be completely removed without causing serious injury to the tree beyond impairing its strength — which is the most serious consideration of all, however, because the limbs may break off or the tree may blow over. Decaying wood can be of no use to a tree; on the other hand, it may act detrimentally, and therefore it should be removed.

The rotten part should be cleaned out thoroughly. A mallet, a chisel, and a gouge are the chief tools needed. If the rot extends for a considerable distance down the limb, a hole, which will serve as a drain (Fig. 11), should be bored at the lower extremity. On ornamental and shade trees the cavities are often filled with cement. Whether this practice is to be followed in the apple orchard depends on the extent of the injury and the exposure of the orchard to wind. In any case the interior surface of the cavity should be coated with coal tar.

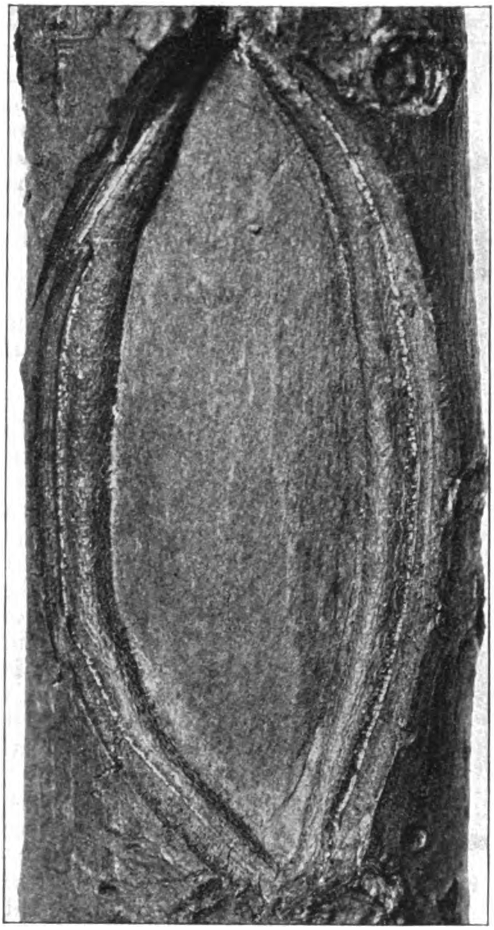

FIG. 12.— *A wound resulting from the removal of a canker on a limb. Note the proper shape of the wound. The canker was cut out on May 19, 1913; the photograph was made on October 17, 1913*

Treating cankers

The cutting-out of cankers is a method to be employed when the orchardist is satisfied that the value of the limb warrants it. An attempt to remove all kinds and sizes of cankers from an infested orchard, without regard to such a consideration, is likely to result in discouragement with the whole matter, and this practice is neither a good nor a paying one. The grower's judgment must guide him.

Certain tools have been found advantageous for this work. A drawshave for use in removing diseased bark, and a farrier's knife for trimming the margin of the wound, are the chief tools needed. The knife must be sharp, for a dull edge may injure the growing part. The pruner should not wear heavy leather-soled shoes, since canker fungi may get into the bark through wounds caused by such shoes. It is suggested that rubber boots, or a similar type of soft-soled shoes, be worn in connection with such operations.

In treating cankers it is necessary to determine the limits of the diseased tissue. This may be done by examining the canker externally or by shaving off bits of bark until the line of discoloration is located. The depth of the cut depends on the depth of any indication of disease, that is, discoloration. If the canker is for the most part superficial, penetrating

the wood only in spots, the bark may be removed as described above, the deeper spots being rimmed out with a farrier's knife. If the fungus has entered the wood, either locally or in long streaks, the discolored part must be removed. If the streak extends for a considerable distance, the case may warrant the removal of the whole limb. So far as possible the wound when finally shaped should be pointed above and below (Figs. 12 and 13), as this facilitates healing; if the cut is left in a rectangular form, the upper and lower edges heal more slowly (Fig. 14). The edge of the wound should be cut at right angles to the surface of the bark; cuts made otherwise will result in a certain amount of dead bark, which makes an easy entrance for canker fungi (Fig. 14).

FIG. 13.— *Good healing after about two years*

Wound dressings

It is a common, but false, belief that some substance may be applied to the surface of a wound to accelerate healing. No wound dressing can induce more rapid callus formation, but it has been found very desirable and helpful to split the edge of the callus each spring, next to the wood, in order to stimulate wide spreading of the callus. The activity of the healing process depends on the character and position of the wound and the time of year when the wound is made, rather than on protective coverings. The sole object of painting a cut surface is to protect the heartwood from decay until the new growth, which forms from the growing tissue immediately beneath the bark, has had time to develop over the exposed dead wood and protect it from decay (Fig. 15). The fundamental requirements of a wound dressing, then, are that it be a preservative and a preventive. It should have antiseptic qualities, and should be fluid, reasonably inexpensive, and easily prepared and applied; it is essential that it give a complete covering; it must be impervious to air and water, must be durable, and must not injure nor kill the tissues nor interfere in any way with the healing process (Fig. 16).

Preparations that meet all these requirements are not to be obtained. The substances most commonly used are paint, asphaltum, and tars. Paint is an inefficient covering; asphaltum, once applied, gives good protection, but it is more difficult to prepare and to apply because it must be liquefied by the use of heat. Asphaltum is more readily available if it is dissolved in gasoline. This combination has been used on apples by Mr. Hazleton, of Le Roy, New York, and it appears to give satisfactory results.

The writer has used coal tar for the past three years with good success

FIG. 14. — *Poor shaping of the wound. The canker was cut out in July, 1910; the photograph was made in August, 1911. The healing was irregular and there was little callus at the ends. The edge of the wound should have been cut perpendicular to the surface of the wood. Note that a certain amount of dead bark remains intact just outside the callus, making a ready point of entrance for fungi*

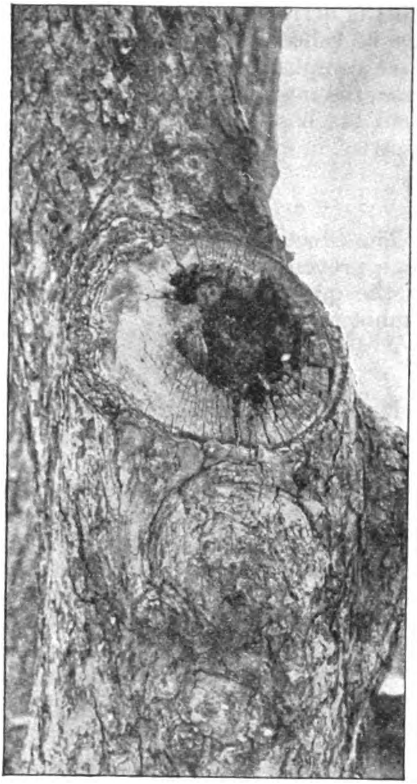

FIG. 15.—*A good cut which is decaying for lack of protection by a wound dressing*

FIG. 16.—*Healing of a wound. Photograph made two years after the removal of a limb*

This is derived in the manufacture of artificial gas from coal. It should not be called gas tar, which is a term more loosely used. Some growers have complained of injury to trees from the use of coal tar, but in such cases the material has usually proved to be something other than coal tar. Coal tar has been used safely and successfully on peaches, plums, and cherries, in experiments conducted by members of this department.

Spraying

The effectiveness of spraying for canker is a question frequently raised. As a preventive this operation is worthy of attention; as a cure it is out of the question, for once the fungus is in the bark the spray material cannot reach it.

Top-working on resistant stock

If an orchardist desires to grow susceptible varieties, the canker menace may be obviated to a considerable extent by working over the larger limbs of more resistant varieties to the one desired. This has been done with apparent success in a few instances. The difficulties involved are that pruning must be done every year in order to remove all sprouts from the stocks, and that the renewal of old branches cannot be effected so rapidly. Such treatment also throws the bearing area higher in the air; so that in the case of erect-growing varieties such as the Twenty Ounce, it makes pruning, spraying, and picking more difficult.

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CORNELL UNIVERSITY

AGRICULTURAL EXPERIMENT STATION OF

THE COLLEGE OF AGRICULTURE

Department of Entomology

POULTRY PARASITES[1]

SOME OF THE EXTERNAL PARASITES THAT INFEST DOMESTIC FOWLS, WITH SUGGESTIONS FOR THEIR CONTROL

GLENN W. HERRICK

Domestic fowls constitute one of the most important sources of food supply in America. In 1911 the value of poultry in the United States reached a total of $154,663,220, and the value of the eggs produced in the same year in New York State alone amounted to $17,102,000. It is thus evident that poultry occupies an important place in the living economies of the American people, and any pests that affect domestic fowls injuriously should be carefully considered.

There are at least nine different species of lice, several species of mites, and at least two species of fleas that attack the hen. Some of these often occur in great abundance and cause serious injury.

THE BIRD LICE PARASITIC ON POULTRY

All the domestic fowls — hens, geese, ducks, turkeys, peafowls, guinea fowls, and pigeons — are infested with various species of bird lice. These insects are known as permanent parasites; that is, they spend their entire lives on the bodies of their hosts, the fowls, though they may go from one host to another when opportunity offers. In fact, they cannot live for more than a few days, at most, when removed from the fowls.

HOW BIRD LICE INJURE FOWLS

Bird lice have biting mouth parts and do not suck the blood of their hosts. It is doubtful whether any of the lice parasitic on domestic fowls ever get any blood except in case of a wound or a bruise on the host from which blood may issue; in such cases the parasites may eat the dried scales of blood. Blood has been found in the stomachs of bird lice, probably obtained in this manner.

It is generally conceded that the bird lice live on bits of feathers and the scales of the skin. Theobald speaks of them as constantly biting at the skin and causing serious irritation. Other writers hold that the constant movements of the lice cause irritation to the skin by the sharp claws with which the feet of all these parasites are furnished. The presence of the lice starts an irritation which eventually weakens the fowl and gives an opportunity for various diseases to attack it. This seems to be especially true of chicks; if lice are abundant, the growth of the chicks is greatly

[1] Only the commoner parasites of poultry are here described. Technical descriptions of these and other species may be found in Cornell University Agricultural Experiment Station Bulletin 359.

checked, diarrhea seems to follow, and a generally weakened condition may result.

The losses caused by poultry lice are difficult to estimate, but the total must be large. When badly infested, chickens fail to make anything like their normal growth. Theobald [2] gives results showing that at the end of a year chicks infested with lice weighed one pound less than those that had been kept free from the pests, both having had exactly the same food and otherwise the same care. The loss in egg production through the infestation of laying hens must be very great, although there is no way of getting even an approximation of it. Brood hens are often so irritated by lice that many of the failures in hatching must be attributed to their presence. Undoubtedly the presence of lice, by weakening the general constitution of the host, predisposes the fowl to such diseases as gapes, cholera, roup, and similar affections, thus contributing to a considerable indirect loss and injury.

LIFE HISTORY OF THE BIRD LICE

The eggs of the common hen louse (*Menopon pallidum*) are usually deposited in clusters at the bases of the feathers. These clusters of eggs can usually be found, on badly infested fowls at least, on the feathers about the vent. When magnified, a single egg is seen to be a very characteristic and striking object. It is white and is covered with glasslike spines, many of which terminate in an anchor-shaped hook. The free end of the egg is furnished with a cap, or lid, which bears at its apex in the center a long, lashlike appendage. This cap is pushed off by the young when it issues from the egg. The eggs are fastened very tightly to the feathers of the fowl.

No very definite information has ever been obtained as to the time it takes the eggs to hatch. All available information seems to indicate that the eggs hatch in a few days under ordinary conditions, and consequently any treatment given to fowls in order to rid them of lice must be repeated in ten days or two weeks.

The young are almost white when they emerge from the eggs; but as they grow older the skin becomes harder and brown in color, and in many species bears certain conspicuous brown and black spots and bands, which form rather characteristic markings. The young resemble the parents in shape and appearance, although the head is usually large in proportion to the body and the abdomen is short and stout.

So far as the writer is aware, the number of molts passed through by these lice has never been definitely determined for any species. Theobald says, "Some kept by the author molted as many as twelve times, but this surely must be exceptional." Nor has the length of these molting stages been determined. It seems probable that the adult lice live for a considerable time on the hosts. Theobald has kept the common hen louse alive for nine months on fresh feathers.

THE COMMON HEN LOUSE

(*Menopon pallidum* Nitzsch)

The common hen louse (Fig. 17) is the species most commonly seen on the hen, and therefore is the best known. It can be found, in greater or

[2] Theobald, F. V. The parasitic diseases of poultry. 1896.

less numbers, on almost any hen at any season of the year. Moreover, it passes readily to other domestic fowls that come in contact with the hen, and instances are recorded in which it has infested horses stabled near henroosts.

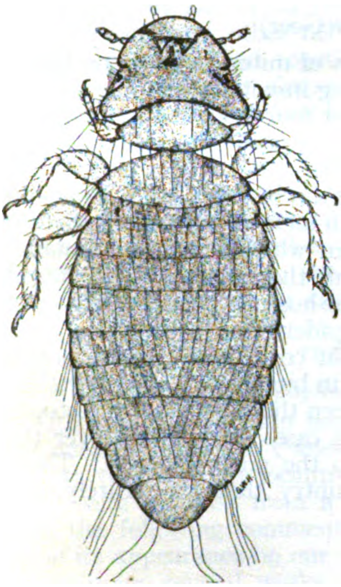

FIG. 17.— *The common hen louse, male*

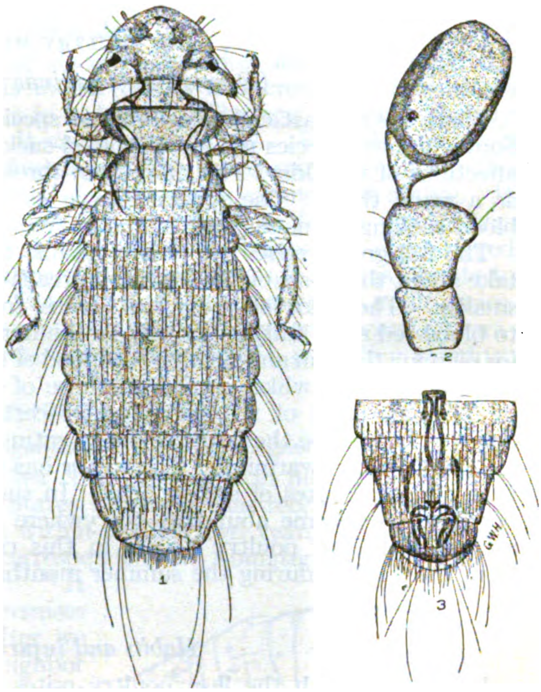

FIG. 18.— *The common large louse of the hen. 1, Female; 2, antenna; 3, end of abdomen of male*

The louse is plainly visible to the eye, being about one-sixteenth of an inch in length. It is of a pale straw color and very active, moving rapidly among the feathers of the fowl. It seems to live on all parts of the fowl's body, but the writer has found it most abundant among the feathers around the vent. It probably causes more injury to hens than does any other species of louse.

THE COMMON LARGE LOUSE OF THE HEN

(*Menopon biseriatum* Piaget)

In the experience of the writer, the next commonest louse on the hen is the species called the common large louse (Fig. 18). It is much larger than the species first described, and somewhat darker in color. This louse is one-tenth of an inch in length, sometimes slightly longer. The male is larger than the female. It is yellowish in color, but is more hairy than the common hen louse, with which it is usually found, and is easily recognized by its larger size.

This species also is active, and apparently passes readily to other hosts for it is found on the turkey and other fowls. It has been present on most of the hens that the writer has examined, and must cause considerable annoyance and injury because of its size and abundance.

THE POULTRY MITE

(*Dermanyssus gallinae* DeGeer)

There are at least eighteen different species of mites parasitic on fowls. Some of these species are merely blood-sucking insects, while others cause affections of the skin. Not more than three or four become serious pests, as a usual thing. The species known as the poultry mite is one of the blood-sucking forms and one of the larger species.

The full-grown mites are plainly visible to the unaided eye. It would take about thirty-six of the females to reach an inch; the males are slightly smaller. The color of the mites varies from whitish yellow normally, to blood-red when fully engorged. In the female the mouth parts are fitted for piercing the skin and sucking the blood of the host; in the male the mouth parts are more jawlike, similar to those of spiders.

The abundance of the mites, under certain conditions, almost passes belief. They have the habit of congregating in bunches, like bees settling on a limb when swarming. The writer has seen them hanging in festoons from the nest boxes of sitting hens. In such cases they spread over the perches and become abundant everywhere in the poultry house. There are probably few poultry houses in this country that are entirely free from these mites during the summer months.

Habits and injuries

In contrast with the lice, poultry mites are not permanent parasites. They are nocturnal in habit, attacking the fowls at night but forsaking their hosts in the morning and hiding in cracks and crevices of the perches, the nest boxes, and the walls of the poultry house during the day. During the night the mites swarm over the fowls, gorge themselves with blood, and cause irritation to their hosts, with an accompanying loss of rest and sleep.

There is no question but that the food of these mites consists largely, if not wholly, of blood. They are often found in great numbers among chicken droppings, but there is no clear evidence to show that they can live on this material or on the juices extracted from it. They can live, however, for a long time without any food at all, and have been kept alive for three months without nourishment. There seems to be authentic proof of their having existed in unoccupied poultry houses throughout a single season at least.

The effect of the mites on fowls is serious and far-reaching. Repp [3] says: "My observations have demonstrated that chickens infested with mites are exceedingly unprofitable. The cost of keeping them is increased and the income from them is very much reduced. . . . . .

[3] Repp, John J. The chicken mite. Iowa State College Exp. Sta. Bul. 69. 1903.

"The hens will cease laying. . . . . In several flocks on which I made observation I found that egg production was greatly reduced or altogether prevented during the spring and summer when, under normal conditions, it would have been at its height."

Life history

The eggs are laid in the hiding places of the mites and mixed with the cast-off skins and other débris in the cracks and crevices. Sometimes several eggs are piled together in a bunch. The egg is white, slightly iridescent, and oval in shape. It varies much in size. Records show that the eggs hatch in from four to five days. The young mite when it hatches from the egg is white in color, and delicate in appearance but active. It has six legs in this stage, but after the first molt the fourth pair of legs appears. Bües[4] believes there is but one molt before the eight-legged stage is reached, and several after that stage, although he was unable to determine the exact number. The length of time from egg to adult varies, apparently according to the supply of food. There are several generations in the warm season and the mites increase with exceeding rapidity.

THE COMMON HEN FLEA

(*Ceratophyllus gallinae* [Schrank] Wagner)

Although the common hen flea (Fig. 19) seems to have been recorded but once before in the United States, the writer has received specimens of it from two different localities within the last two years. In 1912 specimens were received from a correspondent in Abington, Massachusetts, with the following comments: "It made its appearance on our premises last summer, several weeks after we bought some pullets from a neighbor who had returned from California three or four years previously. We had never seen anything of the kind up to that time." The specimens sent were caught on the walls and the ceiling inside the henhouse. In the following year specimens of the fleas were received from Barker, New York. These were collected from "a hen's nest in the henhouse where these fleas live and breed." There are thus two definite records of the appearance of this flea in the United States, and doubtless it may be found in other localities. Both correspondents state that it is a very annoying pest, especially to human beings. One says: "They have certainly bitten me severely and my husband also. They poison me so that the bite will be troublesome for two or three weeks afterwards." The other says: "When one gets an opportunity to bite it will bite several times in a short distance. The bites soon become much swollen, are red, and itch intolerably."

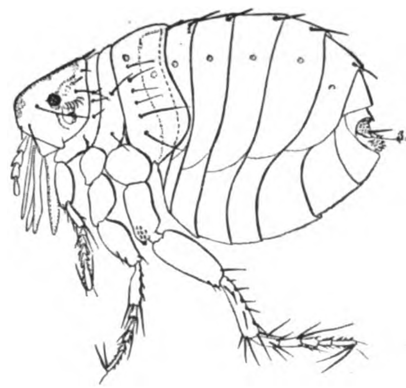

FIG. 19.— *The common hen flea*

[4] Bües, C. R. A. Two external parasites of poultry. Unpublished thesis, Cornell University. 1906.

METHODS OF CONTROLLING THE PARASITES OF DOMESTIC FOWLS

The measures of control here recommended are the results of experiments through several years, more especially with the chicken mite in the Gulf States, where it is especially prominent as a pest of domestic fowls.[5]

Lice, chicken mites, and hen fleas are all responsive to much the same treatment. What is effective for one is, broadly speaking, effective for all, though the lice may call for additional and special treatment. The suggestions given cover the methods by which the parasites may be held in check.

Necessity of clean surroundings and of light

From work with the poultry mite and the hen flea extending over several years, the writer is convinced that the most potent cause of the presence and increase of these parasites is filth — under which may be included droppings, decaying and decayed eggs, and bits of decayed ma-

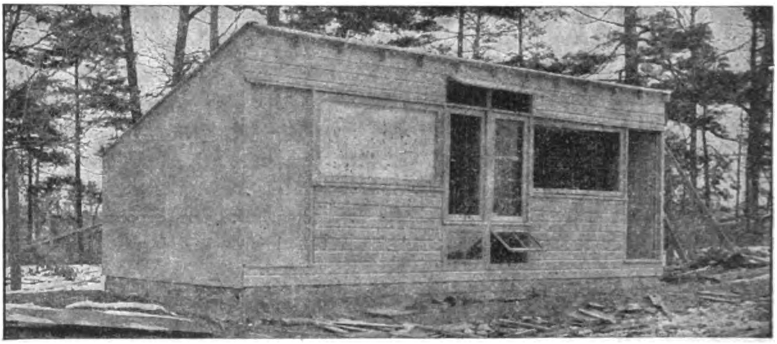

FIG. 20.— *Poultry house providing abundance of light and air*

terial of all kinds. Mites especially are found in great numbers in the filth that has sifted through the straw and that lies at the bottom, in the corners, and in the cracks, of the nest. If a partly hatched egg happens to be broken in the nest the mites literally swarm over it. The filthier the nest becomes from droppings and broken eggs, the more abundant become the mites.

Lack of light is another cause of the presence and increase of mites and other parasites. Many persons believe that almost anything will answer for a poultry house. The only light that enters many poultry houses is what filters in through cracks and through a small door, which may or may not be allowed to stand open.

Such a house as the one shown in figure 20, facing the south, is almost ideal so far as obtaining the maximum amount of sunshine and air is concerned. The open windows should be fitted with cloth curtains fastened to wooden frames hung on hinges. During the day in pleasant weather the curtains may be swung up out of the way. At night they may be let down to close the windows, thus making the house warmer but allowing sufficient air to enter for ventilation.

[5] Herrick, G. W. The chicken mite. Mississippi Agr. Exp. Sta. Bul. 78. 1902.

Inside of poultry house [6]

The poultry house should be high enough and roomy enough inside so that one can go in and walk about with some degree of comfort and pleasure. It is a place that should be visited every day in order that it may receive proper attention. A poultry house built in such a way that one has to crawl through a small door in order to enter, and then go groping around in semidarkness, half bent to the ground for fear of bumping the head against the roof, will receive few visits and scant attention.

The inside of the house should be planned so that nearly, if not quite, everything — perches, dropping board, and nest boxes — can be removed, leaving nothing but the four bare walls. It would be advantageous to have the floor made of concrete. This would aid in insuring dryness, cleanliness, and freedom from parasites. As few pieces of timber as possible should be nailed permanently to the walls of the house, the object being to eliminate everything possible that might afford a hiding place for the parasites and protect them from whatever insecticides might be used. In such a house every part of the walls can be thoroughly treated with kerosene oil, carbolic acid, or any other insecticide. Perches, nest boxes, and other fixtures are also much more easily cleaned and treated if removed from the house than if they are in place.

To clear an infested poultry house of mites

It often happens that a poultry house becomes infested with mites from floor to roof and in every nook and cranny. If the house is of the older type and not too valuable, it may be justifiable to burn it and build anew. In any case the perches and nests should be torn out, in order to facilitate the application of insecticides. The next thing to do is to clean the walls and floors by giving them a thorough sweeping. The inside of the house should then be sprayed with kerosene or crude petroleum. It is best to begin at a certain place and go over walls and floor with the oil, applying it with considerable force by means of a pump and not stopping until every square inch has been covered. The liquid should be forced into cracks and crevices between the boards. The oil will kill all the eggs that are hit, but some eggs will surely escape being touched. As it takes from four to five days for the eggs to hatch, the walls should be gone over again in about a week in order to kill the young mites that appear in the meantime. In another week a third application may be necessary.

If it is thought preferable, the kerosene or crude petroleum may be made into an emulsion [7] and diluted to ten or fifteen per cent, which will kill all the mites actually hit. The emulsion is made as follows: One-half pound of laundry soap or whale-oil soap is shaved fine and dissolved in one gallon of water. The soap is best dissolved if the water is nearly or quite at the boiling point. When the soap is dissolved and the water is hot, it is removed from the fire, 2 gallons of kerosene oil is added, and the mixture is agitated or churned violently until a white, creamy emulsion is formed. The best way to produce the emulsion is to pump the liquid back into itself through the pump until the mixture

[6] Herrick, G. W. The chicken mite. Mississippi Agr. Exp. Sta. Bul. 78. 1902.
[7] Repp, John J. The chicken mite. Iowa State College Exp. Sta. Bul. 69. 1903.

becomes creamy. To make a ten-per-cent emulsion 17 gallons of water is added to the 3 gallons of stock mixture; to make a fifteen-per-cent emulsion 10½ gallons of water is added to the 3 gallons of stock mixture. It is advisable to follow the application of the oil to the walls of the house by a dusting of dry air-slaked lime 3 parts and sulfur 1 part. The windows and doors of the house should be closed and the lime-sulfur should be thrown up to the roof and against the walls until the air is full of the particles. The powder will gradually settle everywhere, much of it entering cracks and crevices.

Isolation of poultry house

It is a well-known fact that the poultry mite sometimes attacks horses, causing sores on the skin and a consequent falling-out of the hair, thus making bald spots at points of infestation. Such attacks on horses by poultry mites occur only when infested fowls have roosted near the stable. Sometimes poultry houses are built adjoining the horse stable, and sometimes fowls are allowed to roost over the horses or even about the mangers. In such cases there is danger of an attack on the horses by mites. For this reason poultry houses should be built at some distance from other farm buildings, especially from horse and cow stables.

Isolation of sitting hens [8]

It is customary on many farms to place sitting hens on eggs in the same house with the other fowls. Mites are likely to infest brooding fowls and to increase enormously in the nests of the fowls. It is therefore desirable to have sitting hens apart by themselves, in a separate room or a separate building. It seems not to be a good practice, however, to set hens in boxes and barrels here and there about the grounds, as this often exposes the fowls to the injurious effects of rain and storms. A woman living in Missouri, writing for an agricultural paper, says: "Hens should be set in a room fitted up for that purpose with nests like those in which they lay. When one is ready to sit, and her service is wanted, a clean box should be obtained, treated with kerosene and carbolic acid, and sprinkled with lime, after which a good soft nest should be built therein."

It must be remembered also that sitting hens need some attention. Not infrequently an egg is broken in the nest. When this happens, the egg should be removed and the others with which it has come in contact should be carefully washed with warm water and wiped dry. If there are droppings in the nest they should be removed. It is of advantage to dust fresh insect powder on the hen occasionally while she is brooding. To facilitate the care and handling of a brooding fowl, some attention and thought should be given to the selection of the right kind of a hen. A quiet, motherly, easily handled hen should be chosen. The idiosyncracies and character of a hen have much to do with her success as a mother.

Treatment of male birds

An infested rooster is a fruitful source of distribution of lice and other parasites throughout a whole flock. Particular attention should be

[8] Herrick, G. W. The chicken mite. Mississippi Agr. Exp. Sta. Bul. 78. 1902.

paid to ridding male birds of these parasites. It would be well to dust the males occasionally in a thorough manner with the Cornell (Lawry) powder. Moreover, when a new cockerel is introduced into the flock it is a good practice to isolate him for a few days and make two or three thorough applications of the powder, being sure that the bird is free from all parasitic affections and diseases before allowing him to be with the flock.

Dust bath for hens

Rice says that "a dust wallow is as essential to a fowl's health and happiness as a water bath is to the health of a human being.[9] It is a common thing to see hens and chickens wallowing in dry dust. They make a hollow place in the ground to conform with the body, and in this they lie, scratching with the feet, fluttering the wings, and elevating the feathers until they stand all fluffy and loose over the body. By scratching, the fowls loosen and pulverize the soil, which is worked down in among the feathers. This is not done wholly for pleasure, although the fowls apparently enjoy it; the fine dust is an excellent insecticide and aids in controlling mites and lice.

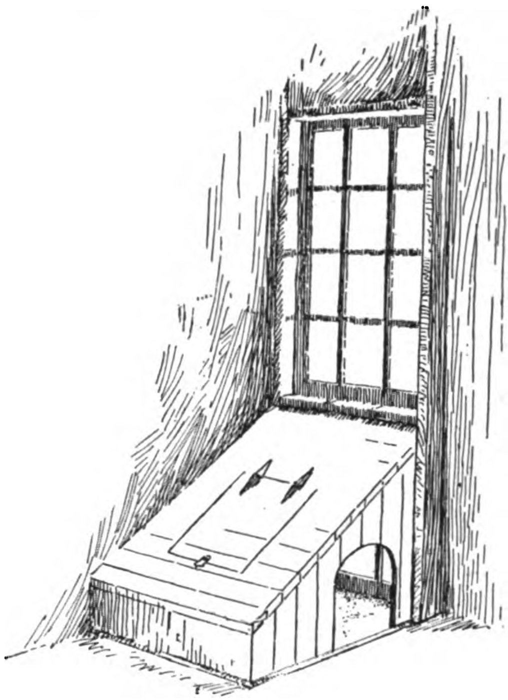

FIG. 21.— *Box for the dust bath*

There are days and seasons of the year when fowls cannot find dry, dusty places in which to wallow. Moreover, where fowls are kept in a pen or a yard they are not always able to find a satisfactory dust bath. In view of these facts a dust bath should be provided and made accessible at all times and seasons.

The finer, lighter, and drier the dust, the more satisfactory it will be. Some kinds of light road dust are good; fine sandy loam is excellent. Whatever soil is used, it is well to lighten it by mixing it with finely sifted coal ashes. It is also advantageous to add now and then small quantities of snuff, sulfur, or dry slaked lime, or all three of these.

The box containing the dust should be set near a window, where the dust will be kept dry and warm and where the sunlight will reach it for a considerable part of the day. The mixture may be kept in an open box, but in this case the fowls that are not dusting are compelled more

[9] Rice, J. E., and Rogers, C. A. Building poultry houses. Cornell Univ. Agr. Exp. Sta. Bul. 274:30. 1910.

or less to inhale the particles of dust. Because of the dust's rising, it is of advantage to keep the fine soil in a covered box with a lid on top for easy filling; a small opening in one side of the box should be provided for the entrance of the fowls (Fig. 21).

Dusting fowls

The measures of control thus far outlined are more especially applicable to the poultry mite, although most of the measures discussed are of value in controlling hen lice also. The lice, as has been pointed out, are permanent parasites and rarely leave their hosts. Therefore applications of oil to the walls of the house, the perches, and other fixtures do not reach the lice on the hens. Light, cleanliness, fresh air, and dust baths are of great value in fighting lice, but it sometimes becomes necessary to actually hit the lice with an insecticide in order to check or destroy them. For this purpose dust insecticides are usually recommended and applied.

The best dust insecticide that the writer has ever known is the Cornell (Lawry) powder. It is made in the following way[10]: Two and one-half pounds of plaster of paris is spread in a shallow pan or tray. One-fourth pint of crude carbolic acid is poured into a cup. and into this is poured three-fourths pint of gasoline. The mixture of acid and gasoline is poured over the plaster of paris and thoroughly mixed. It is then rubbed through a wire window screen on a piece of paper and allowed to stand for from one and one-half to two hours or until thoroughly dry. *It must not be placed near a flame or any heat.* The powder should be kept in a closed can or jar, where it will retain its strength for a long time. The powder is applied by means of an ordinary sifter or with the finger, and is worked in among the feathers about the vent, in the fluff, and under the wings. In extreme cases the application should be repeated in about two weeks. A small pinch of the powder is sufficient for a fowl.

Cost of dusting fowls

It seemed desirable to ascertain the approximate cost of dusting hens with the Cornell powder. Several extensive trials were made in cooperation with the Department of Poultry Husbandry. The work of dusting was performed by students, who proved fairly skillful after a little practice. The results of these trials are shown in the following table:

COST OF DUSTING FOWLS

Pen no.	7	8	8	11	9	11
Number of fowls	367	175	220	401	228	232
Number of students	7	5	4	4	5	5
Time (in minutes)	82	64	53	70	51	47.5
Powder used (in pounds)	3.7	2.3	4.2	5.3	2.3	3.5
Cost of powder	$.13	$.08	$.15	$.19	$.08	$.09
Cost of labor	$1.45	$.56	$.53	$.70	$.64	$.59
Total cost	$1.58	$.64	$.68	$.89	$.72	$.68
Cost per one hundred hens	$.43	$.37	$.31	$.22	$.32	$.29

[10] Circular letter, Department of Poultry Husbandry, Cornell University.

It is seen from this table that the average cost of dusting was a little over 32 cents for each one hundred fowls. This is a little less than one-third of a cent for each fowl. Considering the effectiveness of the powder, this is not an excessive amount to spend for controlling lice.

Dipping fowls

The writer has had no experience in dipping fowls, and on general principles would not advise it. The effect on the fowl is rather severe and the shock must be considerable. The following dips have been used: (1) Pure carbolic acid, 1¼ ounces in 1 gallon of hot water. After the solution has cooled, the fowl should be immersed in it for ***one minute only***. (2) Creolin at the rate of 2½ ounces to a gallon of water may be used instead of carbolic acid.

Mixtures for painting perches

One of the most convenient mixtures for painting perches, nest boxes, or walls of a poultry house, is a combination of crude carbolic acid and kerosene. Three parts of kerosene and one part of ***crude*** carbolic acid make an effective mixture for killing eggs, mites, lice, fleas, and any parasites that may be present in cracks and crevices of the house. There is no objection, other than that of the expense, to using this mixture for spraying walls and perches.

Another mixture for painting perches and nest boxes is known as *cresol soap*.[11] It is made by shaving " one ten-cent cake of laundry soap into one pint of soft water. Heat or allow to stand until a soap paste is formed. Stir in one pound of commercial cresol and heat or allow to stand until the soap paste is dissolved. Stir in one gallon of kerosene. Cresol is a coal tar product and may be obtained from the druggist at about 30 cents per pound. Care should be taken not to get any of it upon the hands or face as it will cause intense smarting. For use as a lice paint, apply undiluted."

[11] Pierce, H. C., and Webster, R. L. Lice on fowls. Iowa State College Exp. Sta. Press bul. No. 18. 1909.

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Department of Dairy Industry

METHODS OF MAKING SOME OF THE SOFT CHEESES

W. W. FISK

For a number of years the Department of Dairy Industry at the New York State College of Agriculture has been making a study of the methods of manufacture of the commoner varieties of soft cheeses, with the object of ascertaining the method that will give the best product for each variety. Tests have been made of various temperatures for setting the milk, various quantities of acid to be used in the milk when set, various quantities of starter, various quantities of rennet extract, and various methods of holding. The method of manufacture here presented for each kind of cheese is the one that was found to give the best results.

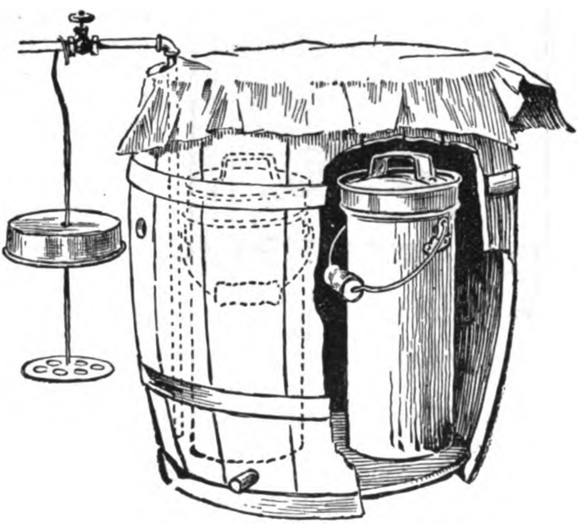

FIG. 22.—*Homemade device for pasteurizing*

There are certain requirements which must be complied with in order that the cheese shall be of prime uniform quality: (1) The cheese must have a good flavor. It can be of no better flavor than the milk from which it is made, and therefore there must be a supply of good milk. (2) The room in which the cheese is made must be so constructed that the temperature can be controlled. This is necessary in order to insure a uniform development of lactic acid. (3) A good, clean starter must be used.[1] The starter not only hastens the development of lactic acid, but also tends

[1] Propagation of starter for butter making and cheese making. By E. S. Guthrie and W. W. Fisk. Circular No. 13, Cornell University Agricultural Experiment Station. (Out of print.)

to correct or overcome bad flavors in the milk. (4) The equipment must include an acid test, by means of which the amount of acid in milk and in whey can be quickly determined at the different stages of manufacture.

PASTEURIZATION

All the soft cheeses can be greatly improved in flavor, body, and texture by pasteurizing the milk. Practically the same results can be accomplished by the use of a homemade pasteurizer as by the improved machines for pasteurizing.

One very easy method of pasteurizing milk, when one of the especially constructed machines is not available and only a small quantity of milk is to be pasteurized, is to cut off the upper part of a barrel and insert a steam pipe in the barrel (Fig. 22). The can of milk to be pasteurized is put into the barrel and the steam is turned on. Care should be taken that the milk is not heated to too high a temperature, and it should be stirred frequently in order to insure even temperature and to prevent a cooked flavor in the product. The stirring may be done with either a dipper or an especially constructed stirrer; in either case the implement should be left in the can and the can kept covered as much as possible while the milk is being heated and cooled, as otherwise contamination is likely to occur. The improved pasteurizers have a mechanical stirrer.

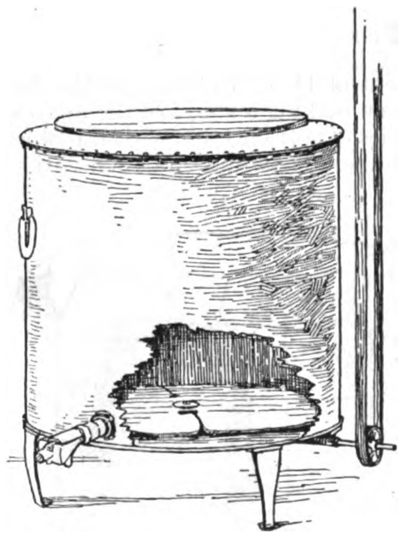

FIG. 23.— *Pasteurizer with mechanical agitator*

An arrangement by which the milk may be stirred without removing the cover is shown in figure 22; but in order to take the temperature — which should be taken with a sterile thermometer — it is necessary to remove the cover. This apparatus also makes a very good outfit for the preparation of starter.

By whatever method pasteurization is accomplished, the milk should be heated to a temperature not above 140° F. for fifteen minutes, and then immediately cooled to the setting temperature. If heated to too high a temperature the milk will have a very undesirable cooked flavor and this will be imparted to the cheese.

Pasteurizing the milk tends to overcome the difficulties encountered in making cheese from gassy milk. Also, cheese made from pasteurized milk is much smoother in texture than cheese made from raw milk, and the yield is slightly greater.

The method of manufacture is the same whether or not the milk has been pasteurized, except that less starter is used with pasteurized milk.

POT CHEESE, BAKER'S CHEESE, AND COTTAGE CHEESE

Pot cheese

Pot cheese is the kind of cheese usually made by the housewife by souring skimmed milk on the stove. It is now more extensively made in dairy plants than was formerly the case. By the use of a thermometer and a clean commercial starter, a product more uniform in quality than would otherwise be possible will be obtained.

Method of manufacture.—The skimmed milk as it comes from the separator should be at a temperature of from 85° to 90° F. It should be run into a vat and should not be allowed to cool below 80° F.; held at this high temperature it will sour or thicken much more quickly than if held at a lower temperature. The souring can be accelerated by the use of a starter, which may be added at the rate of from 0.5 to 5 per cent of the skimmed milk used, depending on the amount of starter that can be made. Generally, the more starter that can be added, the more rapid will be the coagulation and the better will be the flavor of the cheese. As soon as the milk has thickened, the curd is ready to be broken up and separated from the whey. This separation is hastened by the application of heat. Usually the temperature of the curd is raised slightly before it is broken up; since this makes the curd firmer, there will be a smaller loss of curd particles in the whey. The curd may be cut with coarse cheddar cheese knives or broken with a rake. The temperature of the curd should be raised very slowly, at least thirty minutes being taken to reach the desired final temperature. No set rule can be given as to the exact temperature to which the curd should be heated. The temperature should be raised until a point is reached at which the curd, when pressed between the thumb and the fingers, will stick together and not go back to the milky state. This temperature is usually from 94° to 100° F., but the cheese maker must use his own judgment in this respect. If the curd is heated too much it will be hard and dry; on the other hand, if it is not heated sufficiently the whey will not separate from the curd and the curd will be very soft and mushy. When the curd has been heated sufficiently and has become firmed in the whey, it should be removed from the whey. This may be done either by letting down one end of the vat and piling the curd in the upper end, or by dipping out the curd into a cloth bag and allowing the whey to drain, which it does very rapidly.

When dry the curd may be packed in milk cans and shipped, or put into cloths and pressed into small bricks weighing about two pounds. It is usually made into cottage cheese, either at the factory or after shipment.

Yield.—The yields obtained in the various tests are shown in table 1. The yield from one hundred pounds of skimmed milk varies from fourteen to nineteen pounds of cheese, as indicated by the table. The table also shows a slightly higher yield for pasteurized milk. The yield varies with the moisture content of the cheese, being in general greater for cheese with a high moisture content. Too much moisture or whey should not be left in the curd, however, as this would render it too soft to be handled.

Qualities of pot cheese.—Pot cheese should have a clean, pronounced, acid flavor. It should be grainy in texture, but free from hard, dry lumps.

Since no attempt is made during the manufacturing process to control the acidity, the cheese will sour or spoil in a short time.

TABLE 1. YIELD OF POT CHEESE FROM PASTEURIZED AND FROM UNPASTEURIZED MILK

Quantity of milk (pounds)	Treatment	Temperature of milk when starter was added (Fahrenheit)	Temperature of curd when dipped (Fahrenheit)	Yield of cheese (pounds)	Pounds of cheese from 100 pounds of milk	Percentage of starter	Condition of cheese
25	Not pasteurized	75°	94°	4.2	17.0	2.0	....
25		75°	94°	4.0	16.0	2.0	....
25		70°	94°	4.0	16.0	2.0	....
29		73°	91°	5.5	18.9	3.0	Very moist
25		76°	94°	3.6	14.4	4.0	Dry
25		76°	96°	3.9	15.6	3.0	Dry
25		76°	100°	3.5	14.0	2.0	Very dry
25		100°	105°	4.0	16.0	1.3	Dry
25		72°	110°	3.5	14.0	5.0	Very dry
23		75°	100°	3.5	15.2	2.0	....
25		75°	92°	4.2	16.8	1.0	....
Average, 25.18	....	....	....	....	15.8	....	....
	Pasteurized at						
25	150° F.	73°	93°	4.5	18.0	0.7	....
25	150° F.	73°	94°	4.5	18.0	0.7	....
21	160° F.	75°	94°	4.0	19.0	0.2	Very dry
25	155° F.	75°	108°	4.2	17.0	0.5	Very dry
25	145° F.	76°	94°	4.5	18.0	1.0	....
25	140° F.	75°	96°	4.5	18.0	1.3	....
Average, 24.3	....	....	....	....	18.0	....	....

Baker's cheese

Baker's cheese is best made from skimmed milk by the use of commercial starter and rennet extract. This process is longer than that for pot cheese, because it takes longer to get a coagulation and longer for the whey to drain from the curd. The name is due to the fact that the cheese is used to a considerable extent by bakers as filling for pies and cakes.

Method of manufacture.—The milk from the separator should be cooled and held at such a temperature that the acidity will not be above 0.2 per cent at the time when the starter and the rennet are added. If the milk is fresh and sweet when separated it will not have to be cooled below the setting temperature of 75° F. The starter and the rennet should not be added until late in the afternoon, because if they are added too early the coagulation period will be too long. The time from setting to dipping should be about twelve to fifteen hours. At the time when the starter and the rennet are added, the milk should be at a temperature of 75° F.; and this temperature should be maintained until the curd is dipped.

Sufficient starter should be added in the afternoon so that the acidity of the whey separating from the curd the next morning at the time of dipping will be from 0.45 to 0.5 per cent. Generally, from one to three pounds of starter for every thousand pounds of milk is sufficient. The amount of starter to be used depends on the acidity of the milk, the tem-

perature at which the milk is held during the coagulating period, the acidity of the starter, and the length of time allowed for coagulation.

If the milk is too sweet, the starter may be added some time before adding the rennet; usually, however, the rennet is added as soon as the starter has been thoroughly distributed through the milk. The rennet extract should be added at the rate of from one-third to one-half ounce for every thousand pounds of milk. Before it is added to the milk the rennet should be diluted with cold water in the proportion of forty parts of water to one part of rennet extract; this checks the action of the rennet so that it can be evenly mixed with the milk. The action of the starter and the rennet will coagulate the milk in a short time; it should be left undisturbed, however, until the following morning, when the coagulation will be firm and the whey will have begun to separate.

The whey separating from the curd the following morning should have an acidity of from 0.45 to 0.5 per cent. If the acidity is above this amount

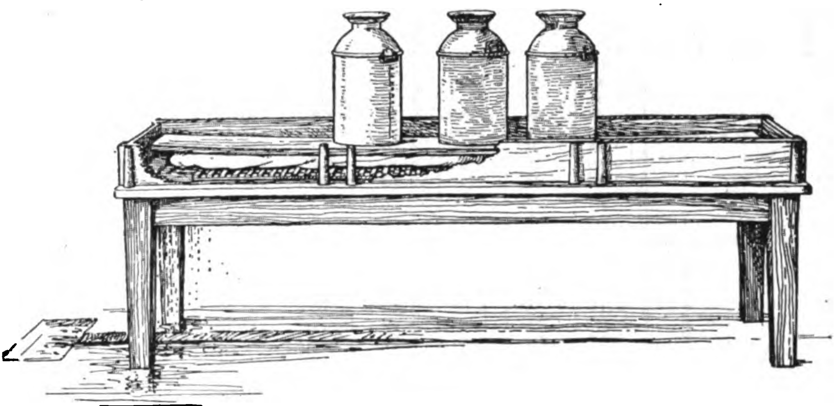

FIG. 24.— *Draining rack, with milk cans full of water used for pressure*

further development should be checked by the addition of salt, since too much acid is very likely to cause an acid cheese; if the acidity has not reached this point, the curd should not be disturbed until it does, as an insufficient amount of acid causes difficulty in separating the curd and the whey.

The separation of curd and whey is best accomplished by dipping them onto a large cloth in a curd sink, allowing the whey to drain away (Fig. 24). The curd should be rolled from the cloth (Fig. 26, page 976), in order that the pieces of curd next to the cloth will not become too dry and also that the whey will have a better opportunity to escape. The expulsion of the whey can be hastened by the application of pressure. This may be brought about by covering the curd with the cloth, placing a board on top of the cloth, and setting cans of water on the board; or the curd may be placed in cheddar-cheese hoops and pressed. The curd should be stirred occasionally so that the particles next to the cloth will not become too dry, as this causes the formation of hard lumps which will not mix with the remainder of the

curd and a lumpy texture results. When sufficiently dry the curd is usually packed for shipment in milk cans or in specially constructed cans.

Yield.—The yield of baker's cheese from pasteurized and from unpasteurized milk is given in table 2. From this table it is seen that pasteurization increases the yield by about two pounds of cheese for one hundred pounds of milk. It is very difficult to compare yields of this cheese because the yield is in proportion to the water content, which varies within wide limits.

TABLE 2. YIELD OF BAKER'S CHEESE FROM PASTEURIZED AND FROM UNPASTEURIZED MILK

Quantity of milk (pounds)	Treatment	Acidity of milk when set (per cent)	Temperature of milk when set (Fahrenheit)	Quantity of starter used (cubic centimeters)	Quantity of rennet used (cubic centimeters)	Acidity of curd when dipped (per cent)	Temperature of curd when dipped (Fahrenheit)	Yield of cheese (pounds)	Pounds of cheese from 100 pounds of milk	Condition of cheese
30	Not pasteurized	0.17	75°	1.00	0.33	0.52	70°	6.0	20.0	Normal
25		0.25	75°	0.50	0.50	0.65	68°	5.0	20.0	Acid
25		0.28	75°	0.50	0.50	0.68	68°	5.0	20.0	Very acid
30		0.22	75°	1.00	0.33	0.43	71°	5.7	19.2	Normal
26		0.18	75°	0.03	0.50	0.47	68°	5.0	19.2	Normal
25		0.19	76°	0.04	0.33	0.45	72°	4.6	18.4	Dry
25		0.18	75°	0.02	0.33	0.46	73°	4.5	18.0	Dry
Av., 26.6	....	.....	.....	.....	.....	.....	.....	.....	19.3	
	Pasteurized at									
478	160° F.	0.17	75°	0.10	4.00	0.45	70°	102.0	21.3	Normal
160	156° F.	0.22	75°	0.10	2.00	0.50	72°	34.0	21.2	Normal
13	200° F.	0.15	75°	0.05	0.50	0.45	70°	3.0	23.1	Very soft
25	150° F.	0.20	75°	0.03	0.75	0.45	71°	5.5	22.0	Normal
25	145° F.	0.18	75°	0.04	0.67	0.51	72°	4.5	18.0	Dry
Av., 140.2	....	.....	.....	.....	.....	.....	.....	.....	21.1	

The yields given in table 3 show the results that may be obtained in actual commercial practice. This table gives the yield of cheese from individual vats for a year, and also the average monthly yield and the total yield for the year.

TABLE 3. YIELD OF BAKER'S CHEESE FOR ONE YEAR FROM INDIVIDUAL VATS

	Pounds of milk used	Pounds of cheese made	Pounds of cheese from 100 pounds of milk		Pounds of milk used	Pounds of cheese made	Pounds of cheese from 100 pounds of milk
March, 1913	700	116.0	16.6	March, 1913 (*continued*)	750	145.0	19.3
	500	86.0	17.2		660	101.0	15.3
	620	97.0	15.6		600	126.0	21.0
	600	98.0	16.3		700	121.0	17.3
	500	79.0	15.8		760	146.0	19.2
	30	5.5	18.3				
	560	98.0	17.5	Total	7,680	1,358.0	.....
	700	139.5	19.9	Average	.....	....	17.7

TABLE 3 (*continued*)

	Pounds of milk used	Pounds of cheese made	Pounds of cheese from 100 pounds of milk
April, 1913.....	750	160.0	21.3
	800	169.0	21.1
	850	165.0	19.4
	650	116.5	17.9
	650	142.5	21.9
	650	147.0	22.6
	550	145.5	26.4
	850	163.5	19.2
	650	114.0	17.5
	560	105.0	18.7
	520	138.0	26.5
	750	112.0	14.9
Total........	8,230	1,678.0	.....
Average.....	.....	....	20.4
May, 1913.....	600	118.0	19.7
	800	146.0	18.2
	400	78.0	19.5
	850	186.5	21.9
	55	7.0	12.7
	800	188.5	23.6
	800	169.0	21.1
	800	148.0	18.5
	750	108.5	14.5
	850	167.5	19.7
	850	182.0	21.4
	570	105.0	18.4
	850	200.0	23.5
Total........	8,975	1,804.0	.....
Average.....	.....	....	20.1
June, 1913.....	800	128.5	16.1
	700	107.5	15.4
	800	160.5	20.1
	560	104.5	18.7
	850	128.0	15.0
	850	168.5	19.8
	800	139.5	17.4
	800	106.0	13.2
	800	153.5	19.2
	800	147.0	18.4
	850	173.5	20.4
Total........	8,610	1,517.0	.....
Average.....	.....	....	17.6
July, 1913.....	850	129.0	15.1
	750	114.5	15.3
	800	129.0	16.1
	500	77.5	15.5
	400	78.0	19.5
July, 1913..... (*continued*)	550	107.5	19.5
	850	169.5	19.9
	800	159.5	19.9
	800	162.5	20.3
	400	56.0	14.0
	700	119.5	17.1
	700	102.0	14.6
Total........	8,100	1,404.5	.....
Average.....	.....	....	17.3
August, 1913...	500	94.5	18.9
	650	137.0	21.1
	600	84.5	14.1
	650	102.0	15.7
	650	81.0	12.5
	700	94.5	13.5
	500	69.0	13.8
	600	108.0	18.0
	580	88.5	15.2
	700	90.0	12.9
Total........	6,130	949.0	.....
Average.....	.....	....	15.5
September, 1913	800	152.0	19.0
	600	121.0	20.2
	700	127.0	18.1
	850	149.0	17.5
	700	129.5	18.5
	700	113.0	16.1
	600	113.5	18.9
	500	87.5	17.5
	500	93.0	18.6
	570	102.0	17.9
Total........	6,520	1,187.5	.....
Average.....	.....	....	18.2
October, 1913...	250	50.5	20.2
	350	69.5	19.8
	350	38.5	11.0
	850	183.0	21.5
	850	192.0	22.6
	750	172.5	23.0
	800	183.0	22.9
	750	164.0	21.9
	750	148.0	19.7
	700	139.5	19.9
Total........	6,400	1,340.5	.....
Average.....	.....	....	20.9

TABLE 3 (*concluded*)

	Pounds of milk used	Pounds of cheese made	Pounds of cheese from 100 pounds of milk
November, 1913.	700	159.0	22.7
	700	156.0	22.3
	750	154.5	20.6
	500	96.0	19.2
	750	146.0	19.5
	350	64.5	18.4
	500	92.0	18.4
	500	86.0	17.2
	500	103.5	20.7
Total........	5,250	1,057.5	.....
Average.....	.....	....	20.1
December, 1913.	400	54.5	13.6
	500	116.5	23.3
	400	88.0	22.0
	500	107.5	21.5
	500	89.0	17.8
	500	102.0	20.4
	500	91.0	18.2
	500	100.0	20.0
	500	111.5	22.3
	500	107.0	21.4
Total........	4,800	967.0	.....
Average.....	.....	....	20.1
January, 1914..	500	112.5	22.5
	500	92.5	18.5
	500	109.5	21.9
	500	113.0	22.6
January 1914... (*continued*)	300	68.0	22.7
	500	92.5	18.5
	500	108.5	21.7
	500	122.0	24.4
	500	95.5	19.1
	500	88.0	17.6
	500	104.0	20.8
	400	87.5	21.9
Total........	5,700	1,193.5	.....
Average.....	.....	....	20.9
February, 1914.	800	175.5	21.9
	500	100.5	20.1
	800	153.0	19.1
	800	142.5	17.8
	500	102.5	20.5
	460	93.0	20.2
	90	13.5	15.0
	478	102.0	21.3
	550	104.0	18.9
	300	29.0	9.7
	500	119.5	23.9
Total........	5,778	1,135.0	.....
Average.....	.....	....	19.6
Total for year.	82,173	15,591.5	.....
Average for year	.....	....	19.0

The average monthly yield for two years is shown in table 4. Since these figures represent the result of two years of commercial work, they show the variation in yield that may be expected. While the average yield per month varies from 15.5 pounds of cheese for one hundred pounds of milk (in February, 1913, and in August, 1913) to 21.6 pounds of cheese (in September, 1912), nevertheless there is little difference in the average yields for the two years.

Qualities of baker's cheese.—Baker's cheese should have a very mild acid flavor. It should be smooth in texture and entirely free from grains and lumps. It will keep for about a week if stored in a cool place.

Cottage cheese

Method of manufacture.—Cottage cheese is very easily made from either pot cheese or baker's cheese. The manufacturing process is the same in either case. The cheese is broken up and salted evenly, two ounces of

TABLE 4. YIELD OF BAKER'S CHEESE, BY MONTHS, FOR A PERIOD OF TWO YEARS

	March		April		May		June		July		August		September	
	1912	1913	1912	1913	1912	1913	1912	1913	1912	1913	1912	1913	1912	1913
Quantity of skimmed milk used (in pounds)	3,310.0	7,680.0	7,750.0	8,230.0	7,590.0	8,975.0	6,150.0	8,610.0	7,500.0	8,100.0	5,650.0	6,130.0	3,650.0	6,520.0
Amount of cheese made (in pounds)	606.0	1,358.0	1,355.5	1,678.0	1,246.5	1,804.0	1,069.5	1,517.0	1,317.5	1,404.5	1,132.5	949.0	790.5	1,187.5
Yield of cheese from 100 pounds of skimmed milk (in pounds)	18.3	17.7	17.5	20.4	16.4	20.1	17.4	17.6	17.6	17.3	20.0	15.5	21.6	18.2

	October		November		December		January		February		Total	
	1912	1913	1912	1913	1912	1913	1913	1914	1913	1914	1912–1913	1913–1914
Quantity of skimmed milk used (in pounds)	5,710.0	6,400.0	6,675.0	5,250.0	4,800.0	4,800.0	6,600.0	5,700.0	7,830.0	5,778.0	73,215.0	82,173.0
Amount of cheese made (in pounds)	1,199.0	1,340.5	1,281.5	1,057.5	991.0	967.0	1,189.0	1,193.5	1,215.0	1,135.0	13,393.5	15,591.5
Yield of cheese from 100 pounds of skimmed milk (in pounds)	20.9	20.9	19.2	20.1	20.6	20.1	18.0	20.9	15.5	19.6	18.3	19.0

salt being used to ten pounds of curd. Cream or butter is usually mixed with the curd, the amount depending on the price to be received for the cheese. Usually, the greater the amount of fat added, the higher will be the price received for the cheese.

Composition.—In table 5 is shown the composition of cottage cheese made by adding heavy cream, testing about 50 per cent fat, to the curd at the rate of one pound of cream for each one hundred pounds of skimmed milk from which the curd was made. The cheese used in Analysis I was taken directly from the refrigerator, so that the exact percentage of fat in the cream was not known. The cream used in the cheese of Analysis II tested 58 per cent fat; that of Analysis III, 50 per cent fat; that of Analysis IV, 50 per cent fat; and that of Analysis V, 42 per cent fat. The table shows that, while the percentage of fat varies somewhat, the percentage of moisture varies between wider limits. The composition of pot cheese and of baker's cheese is about the same as that of cottage cheese, except that the two former cheeses contain only a trace of fat.

TABLE 5. COMPOSITION OF COTTAGE CHEESE

	I	II	III	IV	V	Average
Water	72.8	74.4	74.2	70.9	71.7	72.8
Fat	4.5	3.5	4.0	3.0	3.5	3.7
Protein	16.9	17.5	16.9	20.7	19.5	18.3
Acid (calculated as lactic acid)	2.2	2.0	2.1	2.2	2.0	2.1
Milk sugar	1.8	0.8	1.4	1.2	1.8	1.4
Ash	1.8	1.8	1.4	2.0	1.5	1.7

Marketing.—Cottage cheese is marketed in several different ways. The commonest method of marketing, and by far the cheapest, is to mold the cheese into prints or balls of various sizes and wrap it in parchment paper. If this is to be done, a good practice is to measure each print by an ordinary one-pound butter mold, care being taken that the mold is full and that there are no air spaces in the cheese. The print of cheese can then be cut in two and wrapped, making two half-pound packages—a very desirable size for family use. Paper cut six by eleven inches is required for wrapping packages of this size. The cheese may be put up in paper cartons of various sizes, but these are rather expensive, and are very likely to absorb whey and thereby become so soft that they cannot be handled. In a few cases the cheese is put into glass jelly tumblers, but this is a very expensive method and one not commonly used.

Qualities of cottage cheese.—Cottage cheese should be clean in flavor, resembling fresh butter in this respect. It may or may not be grainy in texture, but it should be free from hard, dry lumps. If it is made from baker's cheese it will be smooth in texture, but if made from pot cheese it will be grainy.

Defects in pot, baker's, and cottage cheese

Pot cheese, baker's cheese, and cottage cheese are liable to the same

kinds of defects. These, with their causes and remedies, may be classified as follows:

I. Defects in flavor
 (a) Acid flavors (indicated by sour taste and smell)
  Causes
   1. Too high acid content of milk used
   2. Too long a period from setting to dipping
   3. Too much starter
   4. Too high a temperature at setting
  Remedies
   1. Use of sweeter milk
   2. Dipping of curd when the whey shows from 0.45 to 0.5 per cent acidity
   3. Use of less starter
   4. Setting at lower temperature
   5. Addition of salt to the curd as soon as it is dipped, in order to check acid development
   6. More rapid working of curd
 (b) Food flavors (characteristic of the foods eaten by cows)
  Causes
   1. Access of cows to such foods as turnips, onions, leeks, garlic, weeds, and the like
   2. Exposure of milk in an atmosphere where any of these foods are exposed
  Remedies
   1. Cows must not be allowed to eat the foods named
   2. Aëration in pure air will help to remove odors from the milk
 (c) Unclean flavors (Under this head may be included any flavors that are not clean or that are foreign to the cheese and not mentioned above. These flavors may be caused in a number of ways. Only the leading causes are mentioned)
  Causes
   1. Use of a starter of bad flavor
   2. Gassy milk
   3. Careless milking
   4. Use of dirty milk cans
   5. Milk not being properly cooled after it is drawn from the cow
   6. Dirty factory conditions
  Remedies
   1. Use of a starter of good flavor
   2. A supply of clean milk
   3. Cleanliness of everything that comes in contact with the milk
II. Defects in body and texture
 (a) Dry and mealy textures (shown by cheese being too hard, firm, dry, and mealy)
  Causes
   1. Too little moisture in the cheese
   2. Too high development of acid
   3. Use of too much rennet extract
  Remedies
   1. Incorporation of more moisture into the cheese
   2. Prevention of development of so much acid
   3. Use of less rennet extract, and provision for a longer coagulating period
 (b) Lumpy texture (shown by hard lumps of various sizes in the cheese)
  Causes
   1. Uneven drying of the curd
   2. Uneven coagulation
   3. Too high a temperature during process of manufacture
   4. Too much variation in temperature
  Remedies
   1. Occasional stirring of curd so that it will dry evenly
   2. Even mixing of rennet through the milk
   3. Provision of a room in which the temperature can be controlled
 (c) Soft, pasty texture (shown by cheese being soft and sticky)
  Causes
   1. Cheese not sufficiently dried
   2. Pasteurization of milk at too high a temperature
   3. Use of too much cream

Remedies
1. More thorough drying of the curd
2. Pasteurization of milk at a lower temperature
3. Use of less cream

NEUFCHÂTEL CHEESE

As its name indicates, neufchâtel cheese originated in France. It is now extensively made in this country, but by different methods from those originally employed in France. It may be made from either whole milk or partly skimmed milk, pasteurized or unpasteurized.

The secret of success in making neufchâtel cheese, as well as the other varieties of soft cheese, lies in having the temperature and the acidity under control. This cheese has never been successfully made in a vat because the temperature of the curd throughout cannot be controlled. The curd nearest the sides and the bottom of the vat will be colder or warmer, as the case may be, than that in the center of the vat. This will result in uneven coagulation and uneven acid development.

The milk for the manufacture of this cheese must be of a clean flavor. Too much attention cannot be given to the milk, because the flavor is one of the most important characteristics of neufchâtel cheese. The flavor of the cheese can be no better than the flavor of the milk from which it is made. Gassy milk gives the cheese not only a poor flavor, but also a poor body.

Method of manufacture.—The manufacture of neufchâtel cheese is similar to that of baker's cheese. The milk to be used should be placed in tall cans holding about thirty pounds. The temperature of the milk should be brought to 72° F., and the cans should then be placed in a vat or a tank of water of the same temperature. The vat or tank should be filled with cans, so that the cans will not float. If there is a room in which the temperature can be controlled, the cans may be placed in this room and it will not be necessary to set them in water. If the milk is received in the morning and there is danger of a higher development of acidity than 0.2 per cent before setting in the afternoon, the milk should be held cold until it is ready to be set, when it should be warmed.

The milk should be set in the afternoon, and at this time the acidity should be not higher than 0.2 per cent. If the acidity is higher than this, cheese of acid flavor and grainy texture will probably result.

With the milk at a temperature of 72° F., sufficient starter should be added so that on the following morning the whey—from which the curd will have separated—will show 0.35 per cent acidity. To accomplish this will require about one cubic centimeter of commercial starter to thirty pounds of milk. After the starter has been thoroughly mixed with the milk, rennet extract should be added, at the rate of one-half cubic centimeter to thirty pounds of milk. Before adding it to the milk, however, the rennet extract should be diluted in cold water. This should give a firm coagulation, which will draw away slightly from the side of the can, and on the following morning a little free whey will appear on top of the curd. If this whey does not show 0.35 per cent acidity the dipping must be postponed until this degree of acidity has developed.

The curd should be very carefully dipped with a ladle onto a cloth suspended at the four corners, and allowed to drain. The contents of each can should be dipped onto a separate cloth (Fig. 26), so that the curd may

dry evenly. Factory cotton is a good cloth for this purpose, because it is of fine enough weave so that the curd particles will not go through;

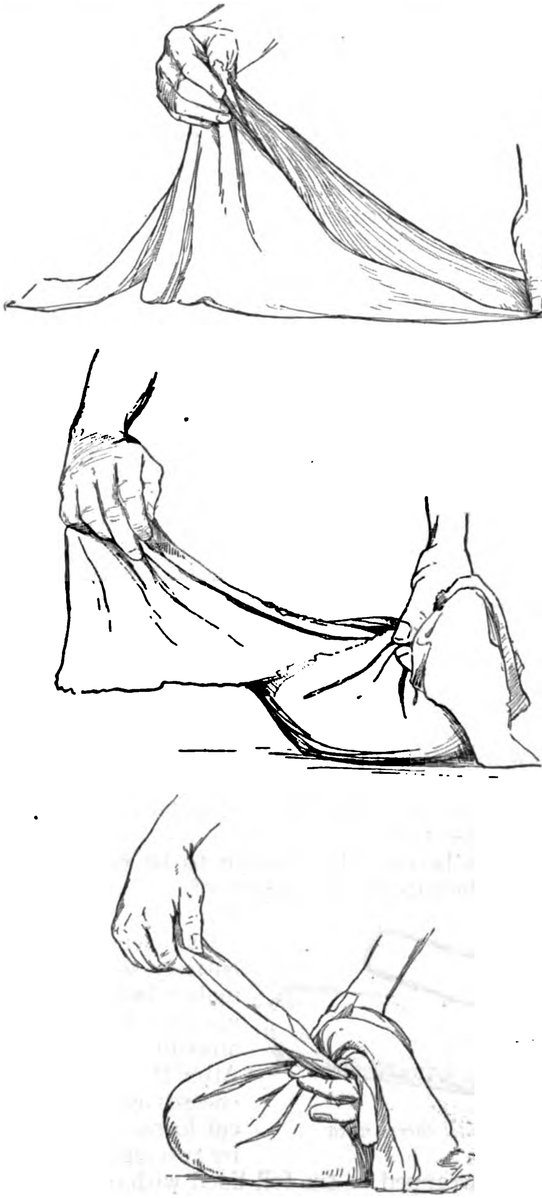

FIG. 25.—*Steps in tying the cheese*

ordinary cheesecloth cannot be used without a considerable loss of curd particles. The curd should not be broken too fine in dipping, as this

prevents the whey from separating rapidly and there will be a greater loss of fat than is necessary. If care is taken not to break the curd it may be poured out of the cans, but it is safer for an inexperienced person to dip the curd with a ladle.

After the curd has drained for a few minutes it should be rolled loose from the cloth by carefully pulling up the side of the cloth. This separates the dry curd from the cloth and gives the whey an opportunity to escape. This process must be repeated several times, until most of the visible free whey has escaped; the curd may then be wrapped up in the cloth, and pressure gradually applied to force out the whey. Too much or too heavy pressure at first will cause a considerable loss of fat, and is likely to force curd particles through the meshes of the cloth. The pressure should be

FIG. 26.—*Draining table, showing different steps in draining and tying cheese*

removed every few minutes so that the cloth may be opened and the curd may be stirred. If not stirred, the curd next to the cloth will become very dry so that it will not mix readily with the softer curd, and this will produce a cheese of lumpy texture.

When the curd has become dry enough to be put up, salt is evenly mixed through it at the rate of two ounces of salt to ten pounds of curd. The question of when the curd is sufficiently dry must be left entirely to the judgment of the maker, because there is no quick method of determining the amount of moisture in curd. After the salt has dissolved, the cheeses are molded into cylindrical forms one and three-fourths by two and three-fourths inches in size (Fig. 27), and wrapped in tin foil lined with parchment cut five by seven inches. A mold of this size makes a cheese weighing about one-fourth pound. The cheeses are then packed in wooden boxes, twenty-five cheeses in a box.

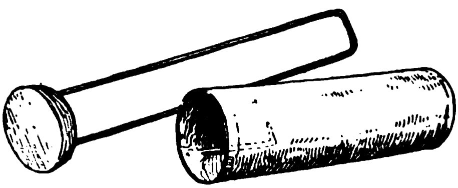

FIG. 27.—*Neufchâtel cheese mold*

TABLE 6. YIELD OF NEUFCHÂTEL CHEESE

Quantity of milk (pounds)	Percentage of fat in milk	Treatment	Acidity of milk when set (per cent)	Amount of starter used (cubic centimeters)	Amount of rennet used (cubic centimeters)	Temperature of milk when set (Fahrenheit)	Acidity of curd when dipped (per cent)	Temperature of curd when dipped (Fahrenheit)	Yield of cheese (pounds)	Pounds of cheese from 100 pounds of milk	Condition of cheese
25	3.0	Not pasteurized	0.16	1.0	0.5	72°	0.37	71°	4.75	19	....
25	4.0		0.18	1.0	1.0	72°	0.40	70°	6.25	25	....
25	4.0		0.16	1.0	0.3	72°	0.38	70°	6.25	25	....
25	3.0		0.19	1.0	0.5	73°	0.50	70°	5.00	20	Acid
25	3.0		0.20	0.5	1.0	72°	0.39	71°	4.50	18	....
25	3.0		0.19	1.0	0.5	72°	0.37	72°	5.00	20	....
Average, 25	....	....	....	....	....	....	....	....	5.29	....	....
		Pasteurized at...									
25	3.0	145° F.	0.18	1.0	0.5	72°	0.41	70°	5.50	22	....
25	3.0	155° F.	0.20	1.0	0.5	72°	0.44	69°	5.75	23	....
25	3.0	180° F.	0.16	2.0	0.5	72°	0.38	71°	6.00	24	Pasty
Average, 25	....	....	....	....	....	....	....	....	5.75	....	....

Yield.—In table 6 is shown the yield of neufchâtel cheese that may be expected. The yield is seen to vary between wide limits, according to the amount of fat in the milk from which the cheese is made, the amount of moisture left in the curd, and whether or not the milk has been pasteurized. In table 7, giving the composition, a very high percentage of water is shown. It is easy, however, to press the cheese a little longer, thus changing both the composition and the yield.

TABLE 7. ANALYSIS OF NEUFCHÂTEL CHEESE*

	Percentage of					
	Water	Fat	Proteids amids, etc.	Milk sugar, lactic acid, etc.	Total ash	Casein
Balland (two analyses)	50.80	25.15	17.60	5.12	1.33	....
	54.80	20.59	14.43	5.98	4.20	....
Blyth	37.90	41.30	23.10	......	3.40	....
von Klenze	51.72	23.99	20.73	......	3.56	....
Martin (two analyses)	56.08	23.34	16.67	1.42	2.49	....
	57.83	21.00	17.00	1.32	2.85	....
Payen (two analyses)	34.47	41.91	13.03	6.96	3.63	....
	36.58	40.71	14.18	9.02	0.51	....
Arnold	37.45	34.60	24.04	......	3.90	....
Johnson	57.25	22.30	15.03	2.94	2.48	....

*From Bulletin 105, U. S. Bureau of Animal Industry.

The figures in table 7 are taken from Bulletin 105 of the United States Bureau of Animal Industry. The composition of neufchâtel cheese as shown in this table varies between wide limits. This is undoubtedly due to the fact that there is no standard for the composition of neufchâtel, and so a cheese is made and called neufchâtel. The composition of the cheese made in the Department of Dairy Industry at Cornell University

TABLE 8. COMPOSITION OF NEUFCHÂTEL CHEESE

	I	II	III	IV	V	Average
Water	55.6	60.3	62.3	58.1	62.6	59.78
Fat	23.0	16.5	17.5	17.0	16.5	18.10
Protein	16.5	17.6	15.3	20.0	15.5	16.98
Acid (calculated as lactic acid)	1.9	2.0	2.0	2.1	1.8	1.96
Milk sugar	1.6	1.6	1.5	1.4	1.6	1.54
Ash	1.4	2.0	1.4	1.4	2.0	1.64

is shown in table 8. The cheese used in Analysis I was taken directly from the refrigerator, so that the percentage of fat in the milk is not exactly known. The cheese used in Analyses II, III, and V was made from milk containing 3 per cent fat, and the cheese used in Analysis IV was made from milk containing 2.8 per cent fat. The fat varies only between narrow limits in Analyses II, III, IV, and V, and the water content does not vary widely.

Qualities of neufchâtel cheese.—Neufchâtel cheese should have a distinct, mild, clean flavor, resembling the odor of freshly drawn milk. The texture should be fairly dry and smooth, with no hard, dry lumps nor grains. There should be no whey leaking from the cheese.

Neufchâtel curd forms the basis of a number of other varieties of cheese, made by mixing nuts, pimento, cream, and other substances with the curd.

CREAM CHEESE

Cream cheese can be made in either one of two ways — by mixing cream with neufchâtel curd, or by a method very similar to that used in making neufchâtel cheese except that cream testing 10 per cent fat is used instead of milk.

Method of manufacture using neufchâtel curd.—When cream is mixed with neufchâtel curd it is difficult to get cheese as rich as that obtained by making the curd from cream testing 10 per cent fat, because if too much cream is added to the neufchâtel curd it will become so moist, and usually so sticky, that it cannot be handled. One pound of heavy cream testing about 50 per cent fat, mixed with five pounds of neufchâtel curd, will ordinarily give a good grade of cream cheese. Care should be taken not to mix the curd so much that it will become salvy. Usually it will be necessary to add a little more salt to the cheese.

This method is much quicker and is less wasteful than making the cheese from cream testing 10 per cent fat.

Method of manufacture using 10-per-cent cream.—When cream testing 10 per cent fat is to be used in making cheese, the method is very similar to that for making neufchâtel cheese. The cream is placed in thirty-pound cans and brought to a temperature of 72° F., in the same way as for neufchâtel cheese, and the same degree of acidity is developed at the time of dipping. A greater quantity of rennet extract is used, this usually being about one cubic centimeter to thirty pounds of milk. This gives a quicker coagulation, thus preventing a loss of fat which would occur if the cream were allowed to rise before coagulation took place. The following morning the curd is dipped onto a cloth, and from this point on the method is the same as that used for neufchâtel.

With this method there is a considerable loss of fat, which is pressed out with the whey. For this reason the method is not extensively used.

Composition.—The cheese used in the analyses in table 9 was made from neufchâtel curd. The cheese used in Analysis I was taken directly from the refrigerator, so that the exact analyses of the milk and the cream were not known. The cheese used in Analyses II, III, and V were made from milk testing 3 per cent fat, and the milk from which the cheese used in Analysis IV was made contained 2.8 per cent fat. Two pounds of cream

was then mixed with the curd from thirty pounds of milk, except in the case of the cheese used in Analysis IV, in which 1.8 pounds of cream was mixed with the curd from thirty pounds of milk. The percentage of fat used in the cream was as follows: Analysis II, 58 per cent fat; Analysis III, 5 per cent fat; Analysis IV, 50 per cent fat; Analysis V, 42 per cent fat. From these figures it is seen that a small difference in the percentage of fat in the cream used has little effect on the fat content of the cheese, but the variation in water content has a greater effect.

TABLE 9. COMPOSITION OF CREAM CHEESE

	I	II	III	IV	V	Average
Water	57.5	50.8	49.6	52.8	50.8	52.30
Fat	23.4	33.0	33.5	28.0	31.5	29.88
Protein	13.6	11.7	12.4	14.9	13.7	13.26
Acid (calculated as lactic acid)	1.6	1.4	2.1	1.4	1.5	1.60
Milk sugar	1.8	1.8	1.0	1.7	1.2	1.50
Ash	2.1	1.3	1.4	1.2	1.3	1.45

Yield.—The yield of cream cheese is a little more than that of neufchâtel cheese, due to the extra fat. The average yield is from twenty-two to twenty-four pounds of cheese from one hundred pounds of 10-per-cent cream, or from the curd from one hundred pounds of milk made by the neufchâtel method with cream added.

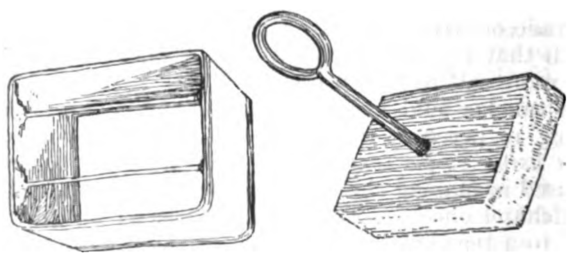

FIG. 28.— *Cream cheese mold*

Marketing.—Cream cheese is always put up in rectangular forms, measuring 1¼ by 2¼ by 2¾ inches. A tin mold used for pressing cream cheese is shown in figure 28. The cheeses weigh about one-fourth pound. They are wrapped in tin foil and put in boxes, twelve cheeses in a box.

Qualities of cream cheese.—Cream cheese should have a clean, mild, acid flavor, resembling well-ripened cream. It should be of a creamy consistency, but not salvy. It should not be grainy in texture, and there should be no hard, dry lumps.

PIMENTO CHEESE

Pimento cheese, which is much used for sandwiches, is made by adding pimentos to neufchâtel curd. A pound of pimentos is sufficient for from eight to ten pounds of curd.

Method of manufacture.—The pimentos are chopped very fine; this is best done by running them through a food chopper. They are then put

into the curd and thoroughly mixed through it. A small pinch of red pepper should be added, to give the cheese a pungent taste. The mixing can be more satisfactorily and evenly done if the pimentos are partly mixed with the cheese and then the whole mass is run through the food chopper. In order to do this and to be sure that the texture will not be salvy, the curd should be cold.

A better color can be obtained if cheese color is added to the milk from which the cheese is made, at the rate of one cubic centimeter of color to thirty pounds of milk. The color, which may be diluted with water or milk, should be added after the starter is added but before the rennet extract is put in.

Yield.—The yield of pimento cheese will be a little more than that of neufchâtel cheese, due to the added pimento; but there will be some loss of curd due to grinding.

Marketing.—Pimento cheese may be molded in either the neufchâtel or the cream cheese mold, and then wrapped in parchment or tin foil. Put up in this way, however, it does not keep very long. Many manufacturers are now putting the cheese into glass jars with screw tops, which hold from three to four ounces. In such a package the cheese will keep much longer, and the original package may be placed directly on the consumer's table and used as long as the cheese lasts. The glass jars are a little more expensive than the tin foil or the parchment paper, but the added expense is made up by the longer commercial life of the cheese.

Qualities of pimento cheese.—Pimento cheese should have a distinct but clean pimento flavor, with a biting taste. It should have a soft, but not salvy, texture, so that it can be evenly spread on bread and crackers. There should be no free whey dripping from the cheese.

CLUB CHEESE

Club cheese is known by a variety of names and is manufactured by many different methods. It is made largely from cheddar cheese, so that it is especially liked by persons who like the cheddar flavor or a strong cheese flavor. It has a soft texture so that it spreads easily, and is therefore much used for sandwiches.

Method of manufacture.—As stated already, there are many different methods of making club cheese. The method used by the Department of Dairy Industry at Cornell University is as follows:

Well-ripened or old cheddar cheese is ground in a food chopper and butter is mixed with it. The older the cheddar cheese, the stronger will be the flavor of the club cheese. Cheese and butter of good flavor should be used. The amount of butter to be used will depend on the amount of moisture in the cheese and the length of time the cheese is to be kept. If the cheese is dry, more butter should be put in, in order to make the texture soft; but if the cheese is to be kept for a long time, too much butter is likely to make it become rancid. Usually one pound of butter to eight or ten pounds of cheese is sufficient.

In order to do away with all lumps in the texture, it is sometimes necessary to run the mixed cheese and butter through the food chopper a second time. While all lumps must be worked out of the cheese, care

should be taken not to work the cheese so much that it will become salvy and sticky.

Usually a little pepper is added, to give the cheese a biting taste. Some manufacturers add a great variety of substances, but these are not necessary and destroy the flavor of the cheese.

Marketing.—Club cheese may be wrapped in tin foil or put up in airtight glass jars. The latter practice, while more expensive, has the advantage of making the cheese keep longer; but for local trade tin foil is just as satisfactory as glass. In filling the glass care must be taken not to leave any air spaces between the cheese and the glass, as this is likely to cause the cheese to mold. A glass jar can be filled and air spaces prevented by first smearing a very thin layer of cheese over the glass.

SUMMARY

1. There is nothing in connection with the manufacture of soft cheeses which after a few trials the average cheese maker cannot master.

2. In order to have the best cheese possible there must be a supply of good milk.

3. A good starter must be used in connection with the cheese.

4. Soft cheeses can often be made and marketed in connection with butter making on the farm.

5. The commercial life of soft cheeses is so short that there must be an easily available and ready market.

6. While there is a large profit in the making of soft cheeses, there are so many losses that in many cases what appears to be a profit will be turned to a loss before the cheese can be sold.

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